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by

KEVIN MICHAEL HART, B.S.

THESIS

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The University of Texas at Austin

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for the Degree of

MASTER OF SCIENCE IN ENGINEERING

THE UNIVERSITY OF TEXAS AT AUSTIN

MAY 1989

CAPILLARY SUCTION TIME TESTS ON SELECTED CLAYS AND SHALES

APPROVED:

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Dr. K.E. Gray

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Dr. Eric P. Fahrenthold

CAPILLARY SUCTION TIME TESTS ON SELECTED CLAYS AND SHALES

APPROVED:

K. E. Gray

Dr. K.E. Gray

E. P. Fahrenthold

Dr. Eric P. Fahrenthold

Dedicated to my parents.

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CHAPTER 1

INTRODUCTION

1.1 Literature review

Shale stability has been an ongoing problem in the drilling of oil wells. Shales contain clays that swell, disperse and slough into the wellbore. These actions result in wellbore instability which leads to decreased penetration rate, lost circulation and other difficulties. Problems associated with drilling problem shale zones have resulted in large additonal expenses in drilling the wells.

In additon to problems encounterd in drilling, problems related to production are experienced. Wellbore instability often results in poor cementation jobs. Also, a deviated hole will lead to poor log response. If methods used to control problem shales are successful, reduced drilling and completion costs and also better production will result.

Almost every well drilled encounters troublesome shale zones at one time or another. Usually only a temporary delay in drilling the well results. However, in some cases, the well has to be abandoned. Shales that the cause the most difficulty contain a high percentage of clays. The difficulties occur when the shale swells after being exposed to the drilling fluid.

According to Van Olphen[16], two mechanisms are responsible for the swelling of clays. These are surface hydration and osmotic swelling. Surface hydration shows little visible signs of swelling. However, the hydration energy is high and large amounts of pressure (>60,000 psi) are required to desorp surface hydration water.

Swelling and softening occurs as a result of osmotic swelling. Osmotic swelling occurs when the concentration of ions at the wellbore wall is higher than that of the drilling fluid. When this is the case, water moves toward the clay surface causing swelling. The amount of swelling depends on concentration of salts in the shale relative to that of the drilling fluid. It follows that osmotic swelling could be controlled if the concentration of the salts in the drilling fluid is higher than that in the shale.

In attempts to overcome the problem of troublesome shales, several classification schemes have been developed utilizing X-Ray diffraction, which involves classifying the shale according to primary clay content such as montmorillonite, kaolinte etc. However, x-ray diffraction does not reveal surface properties of the clay. In 1969, Mondshine[11] classified shales using methylene blue capacity as the primary method. This classification is shown below.

TABLE 1. Mondshine's Classification Scheme

Class	Texture	Methylene blue capacity (me/100g)	Water content	Wt% water	Clay content	Wt% clay	Density g/cc
A	Soft	20-40	Free and bound	25-70	Montmorillonite and illite	20-30	1.2-1.5
B	Firm	10-20	Bound	15-25	Illite and mixed layer montmorillonite-illite	20-30	1.5-2.2
C	Hard	3-10	Bound	5-15	Trace of montmorillonite high in illite	20-30	2.2-2.5
D	Brittle	0-3	Bound	2-5	Illite, kaolin chlorite	5-30	2.5-2.7
E	Firm-hard	10-20	Bound	2-10	Illite and mixed layer montmorillonite-illite	20-30	2.3-2.7

Later, Chenevert and O'Brien classified shales according to clay content. These clays included montmorillionite, illite and chlorite. O'Brien and Chenevert's classification scheme is shown below.[12]

TABLE 2. CHENEVERT AND O'BRIEN CLASSIFICATON SCHEME

Class	Characteristics	Clay Content
1	soft, high dispersion	high in montmorillonite, some illite
2	soft, fairly high dispersion	fairly high in montmorillonite, high in illite
3	medium-hard, moderate dispersion sloughing tendencies	high in interlayered clays, high in illite, chlorite
4	hard, little dispersion, sloughing tendencies	moderate illite, moderate chlorite
5	very hard, brittle, no significant dispersion, caving tendencies	high in illite, moderate chlorite

Dispersion is another property of shales that has presented problems for drilling engineers. Dispersion causes shale particles to disintegrate into the drilling fluid. These solids are difficult to remove and cause problems that could lead to hole washout. Clays are dispersed by either hydration or electrostatic forces.

Over the years, there have been many attempts to overcome difficulties encountered in drilling shale zones. Several researchers have designed both water and oil-based drilling fluids to increase wellbore stability. In 1969, Mondshine[11] developed a technique that determined salinity requirements of an oil-based mud in order to provide adequate inhibition. Chenevert[3] introduced the concept of balanced-activity oil-continuous muds. The basic feature of the balanced-activity muds is that the activity of the water phase of the mud is inert to the shale formation.

Although some success was achieved using oil based muds, cost and environmental factors make it necessary to design a water-based mud to control shale instability. In 1973, O'Brien and Chenevert[12] demonstrated the effectiveness of using Pottasium Chloride as a shale inhibitor. In 1982, Steiger[15] advocated the use of potassium/polymer drilling fluids for shale inhibiton. These mud systems had the added feature of being less expensive and easier to use than oil-based muds.

Over the years, severals tests have been developed in order to overcome problems encountered while drilling problem shale zones. As mentioned earlier, X-Ray diffraction was used to determine clay and mineral content. However, X-Ray diffraction is limited since it does not measure surface properties. In 1969, Darley[5] constructed a model to study borehole stability. Darley's research provided qualatitive insight into the mechanisms of swelling and dispersion. The Methylene Blue test has been used by many researchers to measure cation exchange capacity. As mentioned earlier, Mondshine used the Methylene Blue test extensively in his classification scheme. In 1983, Wilcox and Fisk[20] used the Capillary Suction Time (CST) test and ensilin data to aid in predicting the behavior of the shale zone being drilled. The CST test is a simple test that can be carried out at the rigsite. Using these two tests, Wilcox and Fisk[19] developed another shale classification scheme. The CST test was also used by Lauzon[9] in 1984 in his study of dispersion in shales. Wilcox and Fisk also used the Cst test to measure polymer solid aggregation.

1.2 Formulation of the problem statement

As mentioned in the literature review, various researchers have used X-Ray diffraction, Methylene Blue Capacity, Fluid adsorption (ensilin) and CST data to classify shales and develop drilling fluids that would inhibit shale swelling and dispersion. However, correlative tests on the various procedures with a given shale or clay have not been done.

The purpose of this thesis is to compare the Capillary Suction Time test data with other shale reactivity tests carried out at the Center for Earth Sciences and Engineering. The other tests conducted included:

Ensilin

Methylene Blue Capacity

Specific Surface Area

Gulf Swellmeter

Atterburg Limits

X-Ray Diffraction

By comparing all tests conducted, the behavior of the test shale in the presence of a drilling fluid should be predictable or, at least, consistencies in results noted. This information should assist drilling personnel in evaluating shale swelling and dispersion problems.

CHAPTER 2

EXPERIMENTAL METHODS

2.1 Introduction

The purpose the experimental work undertaken was to classify problem shales using the Capillary Suction Time test along with other data obtained at the Center for Earth Sciences and Engineering. Along with the CST test, the other experiments performed included: Methylene Blue Capacity, Ensilin, Specific Surface Area, Atterburg Limits and X-Ray Diffraction. Below is a listing of the shales and clays tested and the notations used:

1.	Gold Seal Bentonite	(GSB)
2.	Mancos Mudtech	(MMT)
3.	Pierre Mudtech	(PMT)
4.	Standard Texas	(STX)
5.	Standard Wyoming	(SWY)
6.	Standard Arizona	(SAZ)
7.	Texaco Mississippi Canyon	(TMC)
8.	Pierre Texaco	(PTX)
9.	Phillips Ekofisk	(PEF)

10. Phillips Andrews County (PAC)

The CST tests were run using varying shear rate, shear time and KCL concentrations. The shear rate was varied by using different speeds on the Waring blender. Speeds used were 1, 3, 5 and 7. Shear times were 10, 60, 120 and 300 sec. The KCL concentration range included 0, 0.5% and 15%.

2.2 Description of Equipment

The CST apparatus (shown in fig 1) measures the time required for a fluid to travel a fixed radial distance on thick, porous filter paper. The apparatus measures this property by use of electrodes arranged in a triangular manner. When the fluid reaches the first two electrodes, the timer starts, when the fluid reaches the third electrode, the timer stops and the capillary suction time is recorded. The CST device was first used in sewage treatment[20]. Wilcox et al. have used the CST apparatus to characterize dispersive properties of shales. Since the test is easy to use and not time consuming, it can be performed at the rigsite. Besides the CST apparatus and the CST filter paper (Venture Innovations), a Mettler balance and a Waring blender are required to carry out the CST tests.

2.3 Procedure

2.31 Sample preparation

1. Grind sample to pass a 200 mesh sieve.
2. Dry sample at 120^{o} F overnight.

2.32 Test procedure

1. Weigh out 7.5 grams of the shale to be tested.
2. Measure 50 ml of KCL solution being tested.
3. Pour clay sample into the KCL solution and shear the sample at the specified rate and time.
4. Pour aliquot into the funnel and measure the CST.

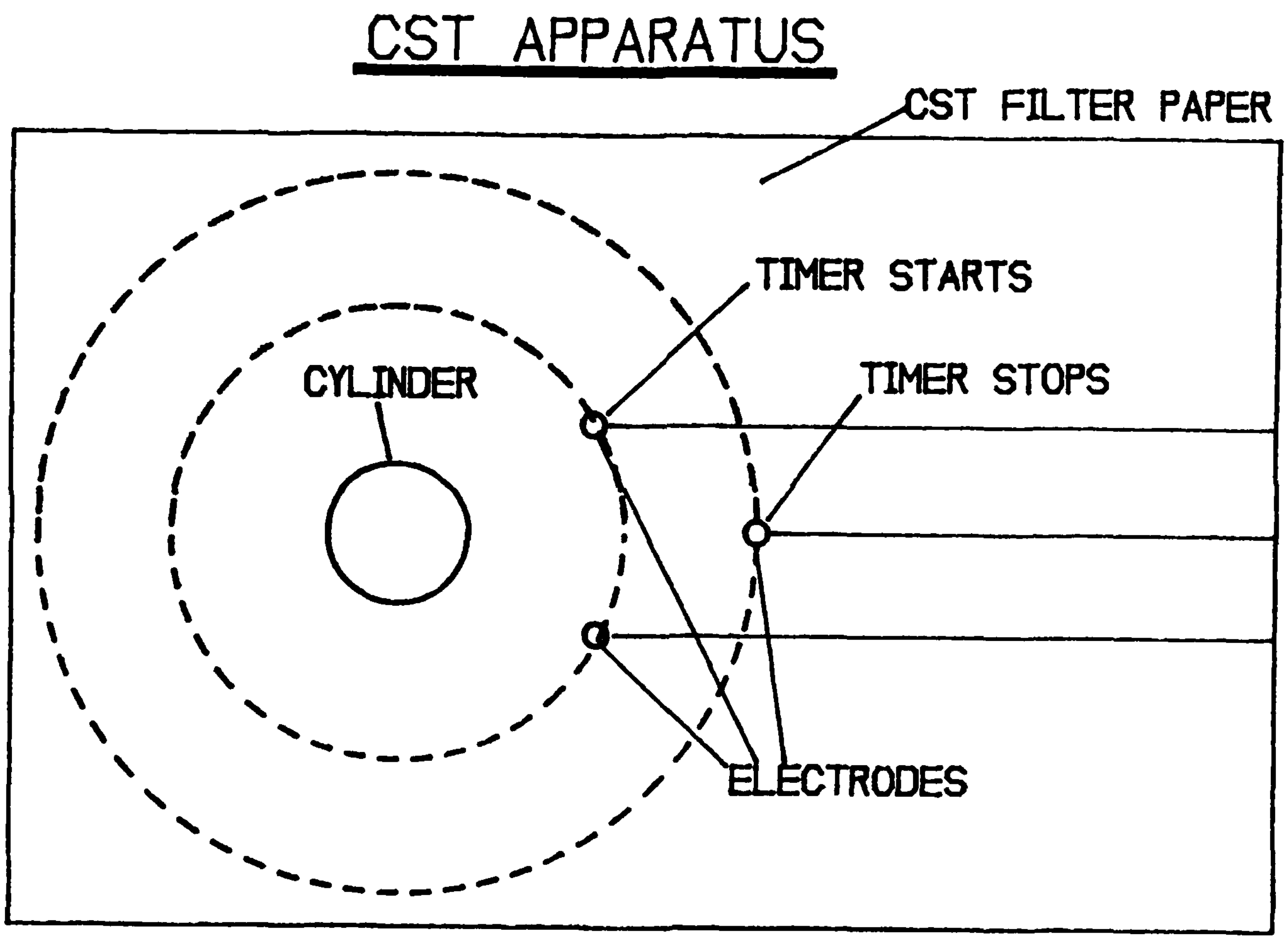


FIGURE 1. CAPILLARY SUCTION TIME APPARATUS

CHAPTER 3

PRESENTATION OF RESULTS

The CST experiments were conducted using varying shear time, shear rate and KCL concentrations. Table 3 shows the CST data obtained using varying shear time and Table 4 shows the data obtained using varying shear rates. The tests shales are abbreviated as shown below.

GSB - Gold Seal Bentonite

PEF - Phillips Ekofisk

PAC - Phillips Andrews County

TMC - Texaco Mississippi Canyon

PTX - Pierre Texaco

PMT - Pierre Mudtech

MMT - Mancos Mudtech

STX - Standard Texas

SAZ - Standard Arizona

SWY - Standard Wyoming

Figures 1-54 are plots of CST vs time and CST vs Shear rate. These plots are intended to show the effect of shear rate and shear time on the CST. Also, all three KCL concentrations are shown on a single plot in order to show the effect of increasing KCL concentration.

TABLE 3. CST, VARIED SHEAR TIME
SHEAR RATE = BLENDER SPEED 7

0% KCL	GSB	PEF	PAC	THC	PTX	PHT	MMT	STX	SAZ	SHY
SECONDS										
2.00	2250.00	35.10	53.30	57.25	105.50	19.55	14.00	115.10	47.70	1710.50
10.00	3215.00	59.00	66.30	91.85	205.95	23.85	15.10	179.95	95.35	1155.90
60.00	4651.00	67.45	133.50	142.40	250.45	33.65	25.75	194.80	238.45	2137.10
120.00	4937.00	66.50	51.70	145.95	234.80	38.00	28.55	581.20	353.75	1838.20
300.00	3086.00	68.60	69.70	65.45	257.50	43.50	29.65	556.75	295.05	1968.30
0.5% KCL										
2.00	243.00	25.10	16.15	29.00	12.65	18.45	9.50	32.55	13.05	45.20
10.00	467.00	38.85	19.35	38.40	21.60	25.30	11.45	45.00	21.10	124.50
60.00	765.00	57.85	25.95	53.55	32.70	32.00	15.25	64.80	35.80	287.90
120.00	756.00	70.90	29.35	50.00	37.90	42.60	22.50	78.50	52.85	518.60
300.00	789.00	66.55	25.60	52.80	42.70	50.00	25.00	87.10	60.00	639.70
15% KCL										
2.00	7.55	8.85	10.10	9.50	8.05	11.60	9.90	13.80	8.95	9.65
10.00	10.10	12.75	9.10	12.50	13.50	11.25	10.25	20.95	9.55	10.65
60.00	14.50	23.15	13.20	20.00	16.45	15.10	13.40	30.40	14.95	16.00
120.00	17.30	25.95	13.35	19.60	13.15	12.30	11.55	30.05	20.90	20.45
300.00	22.00	27.70	10.65	20.75	11.85	14.45	11.85	33.55	35.95	26.85

TABLE 4. CST, VARIED SHEAR RATE
SHEAR TIME = 120 SECONDS

0% KCL	GSB	PEF	PAC	THC	PTX	PHT	MHT	STX	SAZ	SWY
BLENDER SPEED										
4.00	2908.00	118.10	219.40	132.90	300.35	30.90	34.80	222.60	185.75	1880.70
5.00	2958.50	125.35	222.45	131.05	322.25	33.50	38.60	528.25	327.35	2147.90
6.00	4433.50	123.30	258.60	141.75	447.45	32.80	35.70	547.25	339.85	1818.60
7.00	4936.50	133.75	393.75	155.60	300.50	32.10	42.20	495.40	380.40	3685.60
0.5% KCL										
4.00	1035.50	63.00	33.50	56.25	45.65	*	20.30	59.40	39.25	270.10
5.00	841.00	79.40	37.25	62.75	41.20	*	20.15	65.65	43.85	323.80
6.00	1008.50	80.15	33.30	63.25	46.00	*	20.00	65.50	47.40	435.40
7.00	756.00	76.90	36.75	59.20	42.60	*	24.85	67.90	53.90	359.60
15% KCL										
4.00	21.60	21.75	17.75	19.30	13.75	12.60	11.95	28.75	14.25	16.20
5.00	22.65	21.55	18.45	20.00	16.20	14.25	13.35	27.65	15.20	19.20
6.00	24.85	23.65	17.85	22.10	14.45	14.10	11.30	28.80	16.00	16.80
7.00	22.20	25.95	18.00	21.40	11.40	13.95	12.60	31.65	18.90	21.60

TABLE 5. X-RAY DIFFRACTION DATA

SAMPLE	CLAY (%) FRACTION	MONT	MIXED LAYER ILL/SMEC.	KAO	ILL.	CHLOR	MIXED LAYER %EXP.	KAO + CHL
SAZ	100	100	-	-	-	-	-	-
SWY	87	100	-	-	-	-	-	-
GSB	88	100	-	-	-	-	-	-
STX	100	100	-	-	-	-	-	-
PEF	66	53	-	28	19	-	-	28
PMT	44	76	-	5	13	6	-	11
PAC	53	-	78	12	-	10	40	22
TMC	44	-	42	25	33	-	80	25
PTX	57	82	-	-	11	7	-	7
MMT	17	-	32	45	-	23	20	68

TABLE 6

RESULTS OF SPECIFIC SURFACE, METHYLENE BLUE AND ATTERBURG LIMITS TESTS (10,13,18)

SAMPLE	SPECIFIC SURFACE AREA (m^2/gm)	METHYLENE BLUE	PLASTICITY INDEX	ATTERBURG LIMITS LIQUID	ATTERBURG LIMITS PLASTIC	SWELLING INDEX
SAZ	647	129	57	100	43	1.72938
SWY	602	94	619	670	51	10.58905
GSB	574	91	504	555	51	5.87948
STX	540	82	85	115	30	2.1468
PEF	249	30	38	64	26	1.45458
PMT	193	31	27	47	20	0.86579
PAC	182	18	12	28	16	0.75505
TMC	166	21	26	42	16	0.90599
PTX	153	27	41	70	29	1.221
MMT	86	6	N/A	N/A	N/A	N/A

FIGURE 2. CST, 0% KCL

VARIED SHEAR TIME, BLENDER SPEED 7

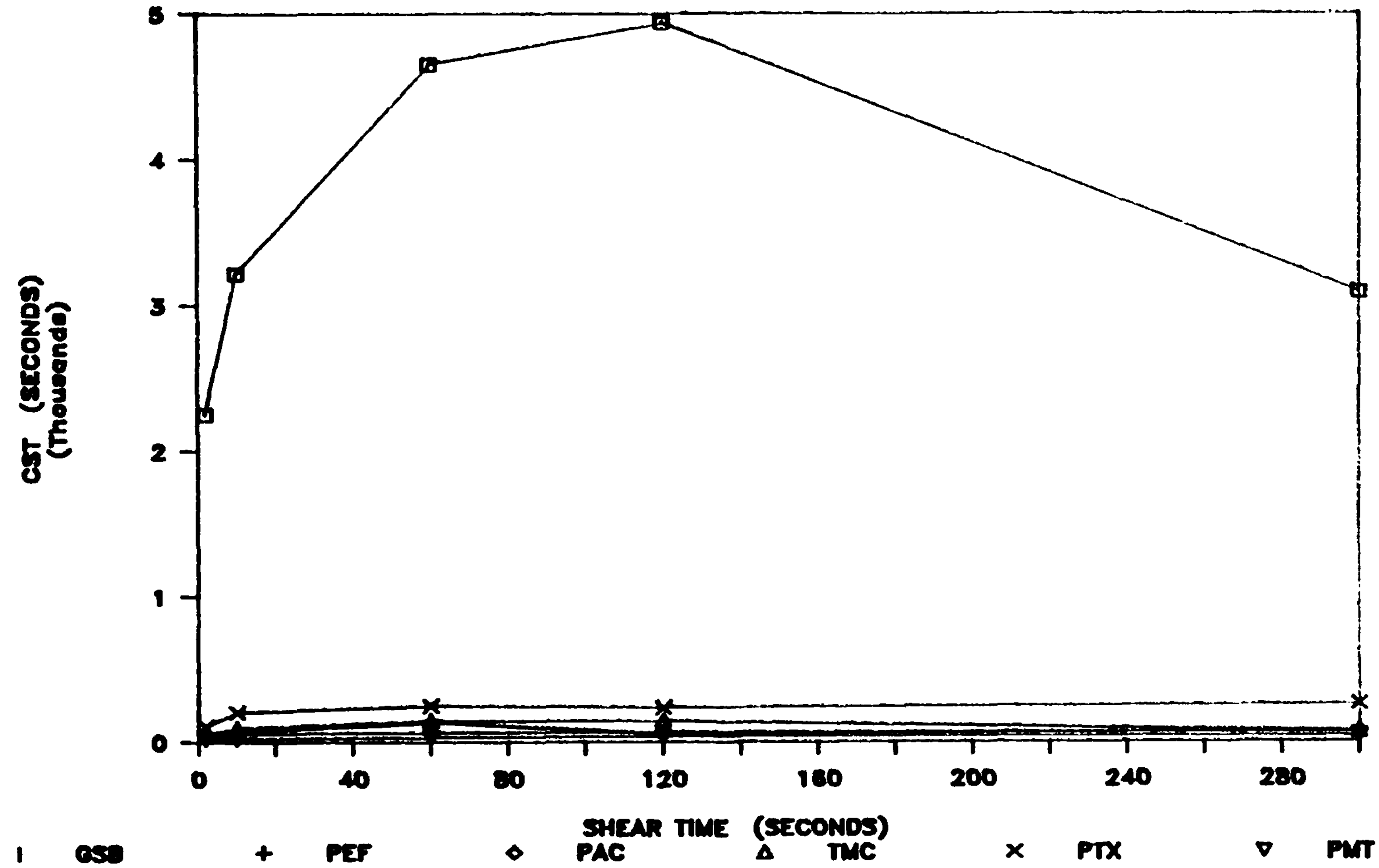


FIGURE 3. CST, 0%KCL

VARIED SHEAR TIME, BLENDER SPEED 7

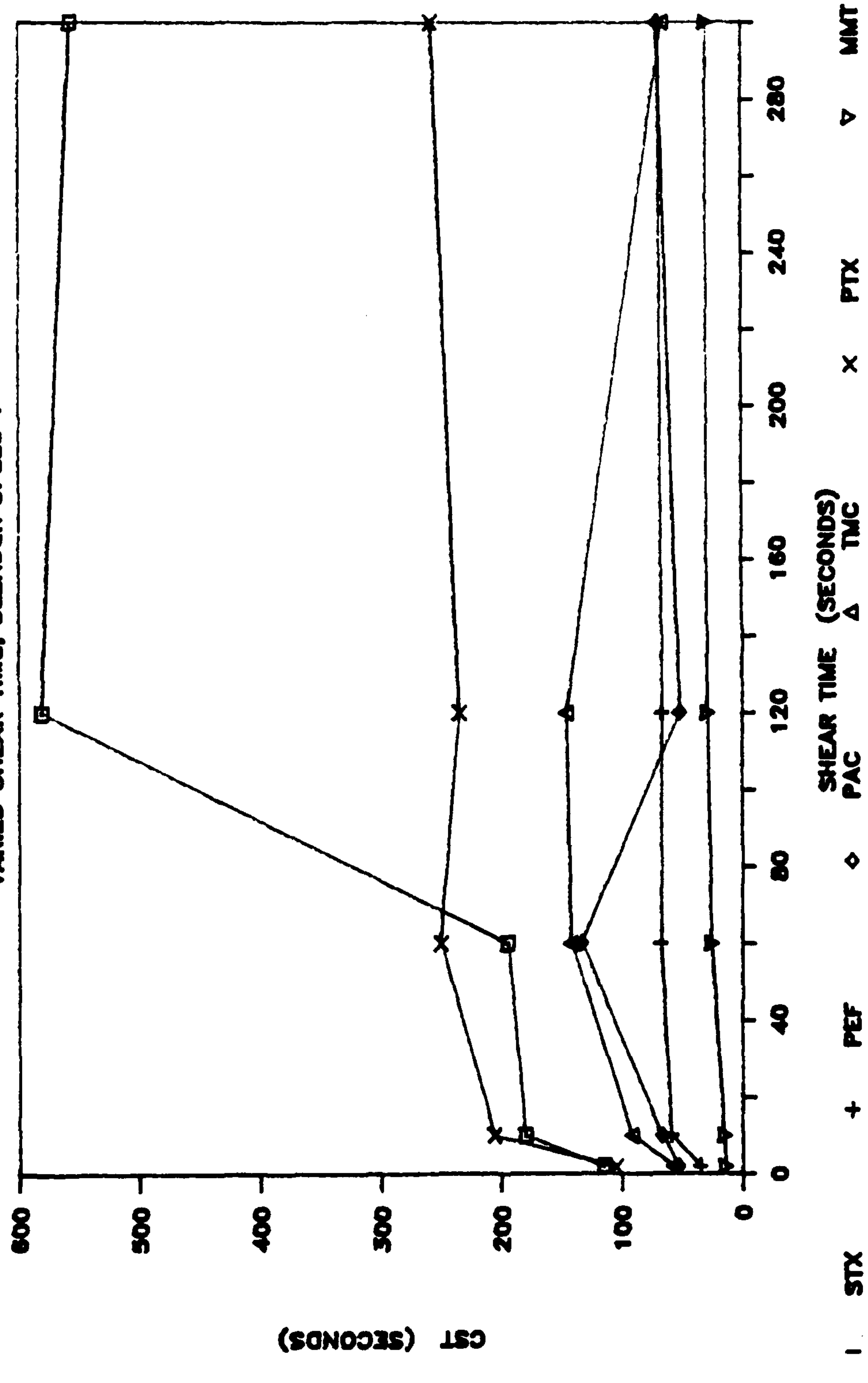


FIGURE 4. CST, 0% KCL

VARIED SHEAR RATE, TIME = 120 SEC

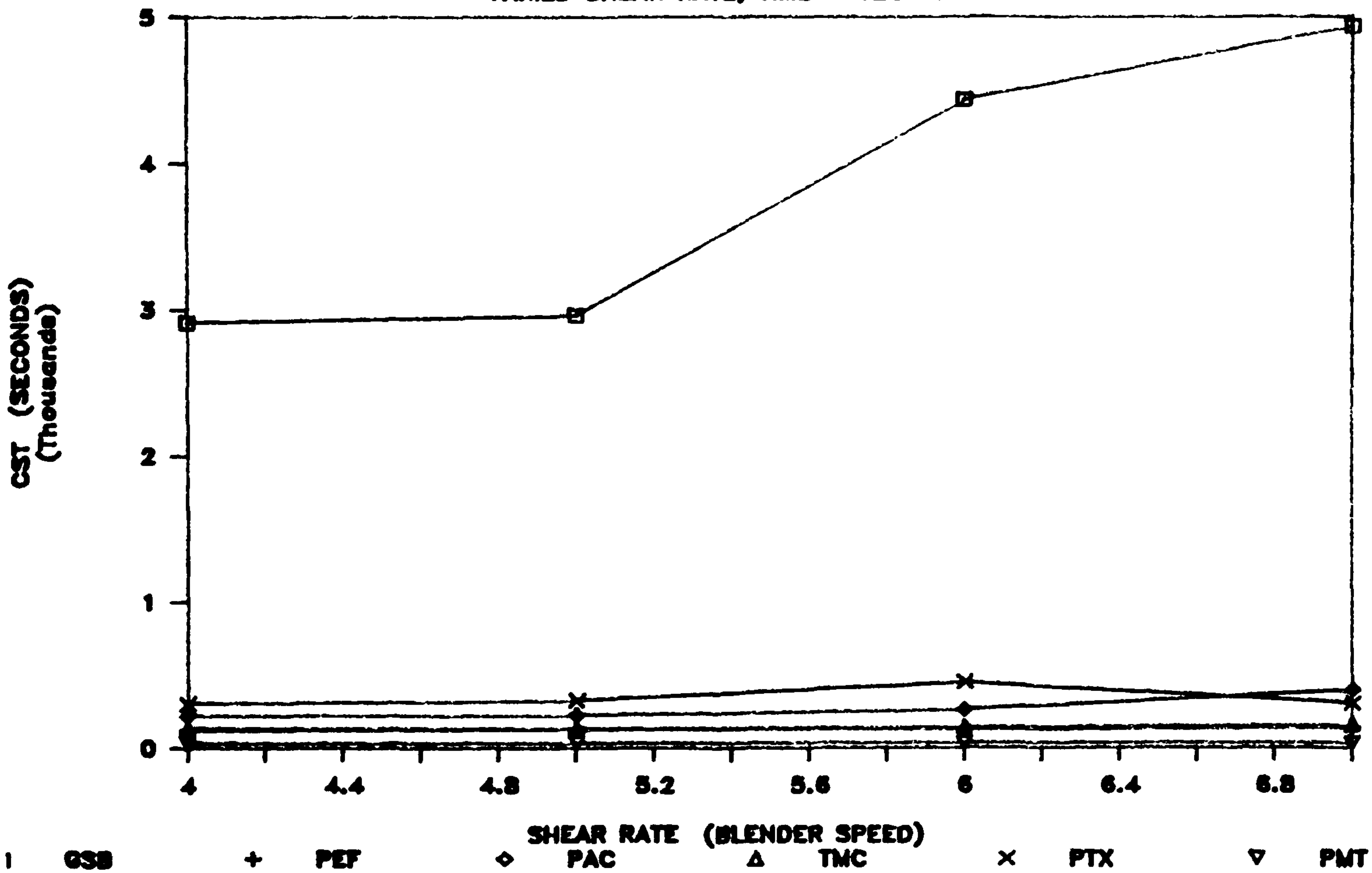


FIGURE 5. CST, 0%KCL
VARIED SHEAR RATE, TIME = 120 SEC

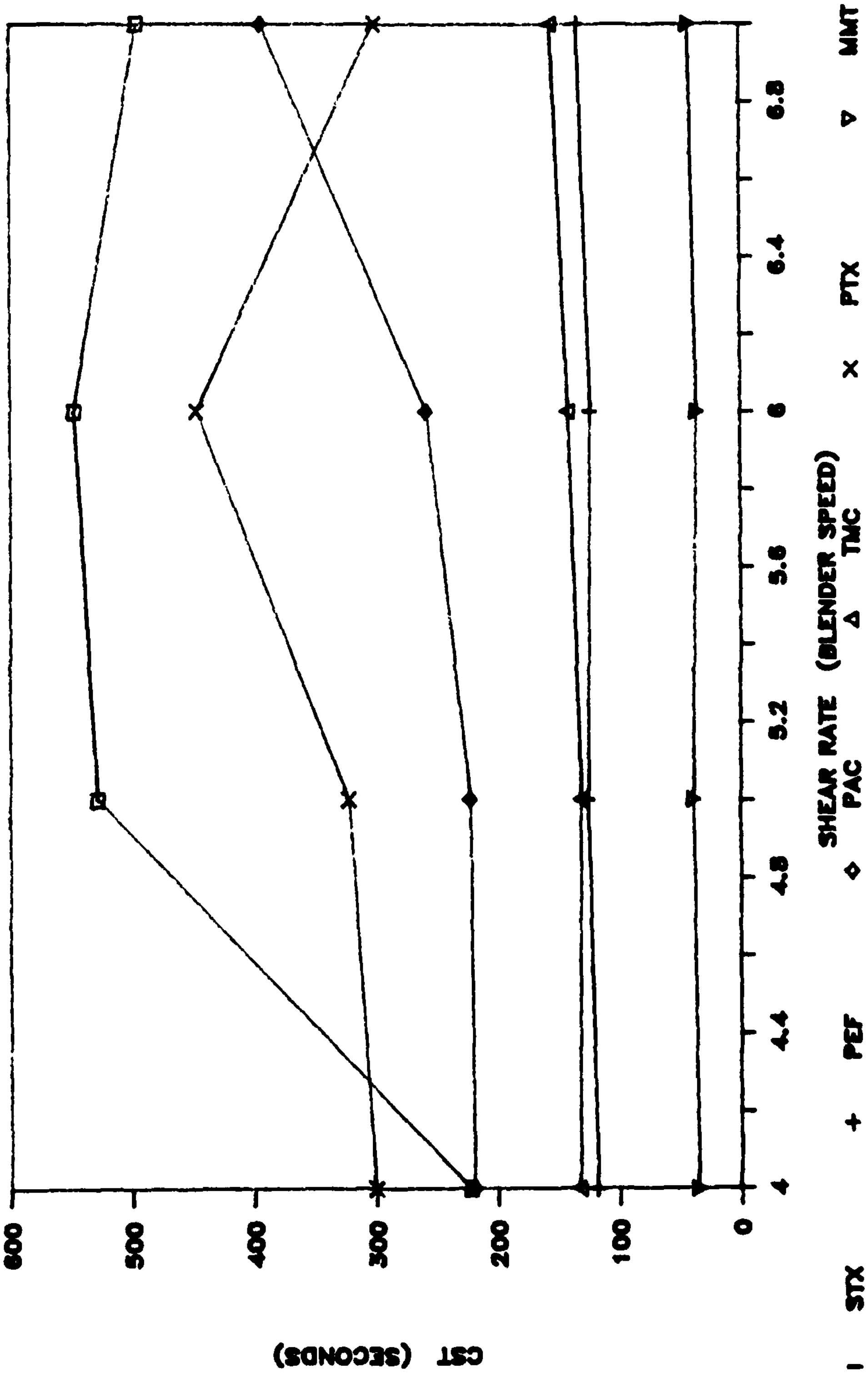


FIGURE 6. CST, 0.5% KCL

VARIED SHEAR TIME, BLENDER SPEED = 7

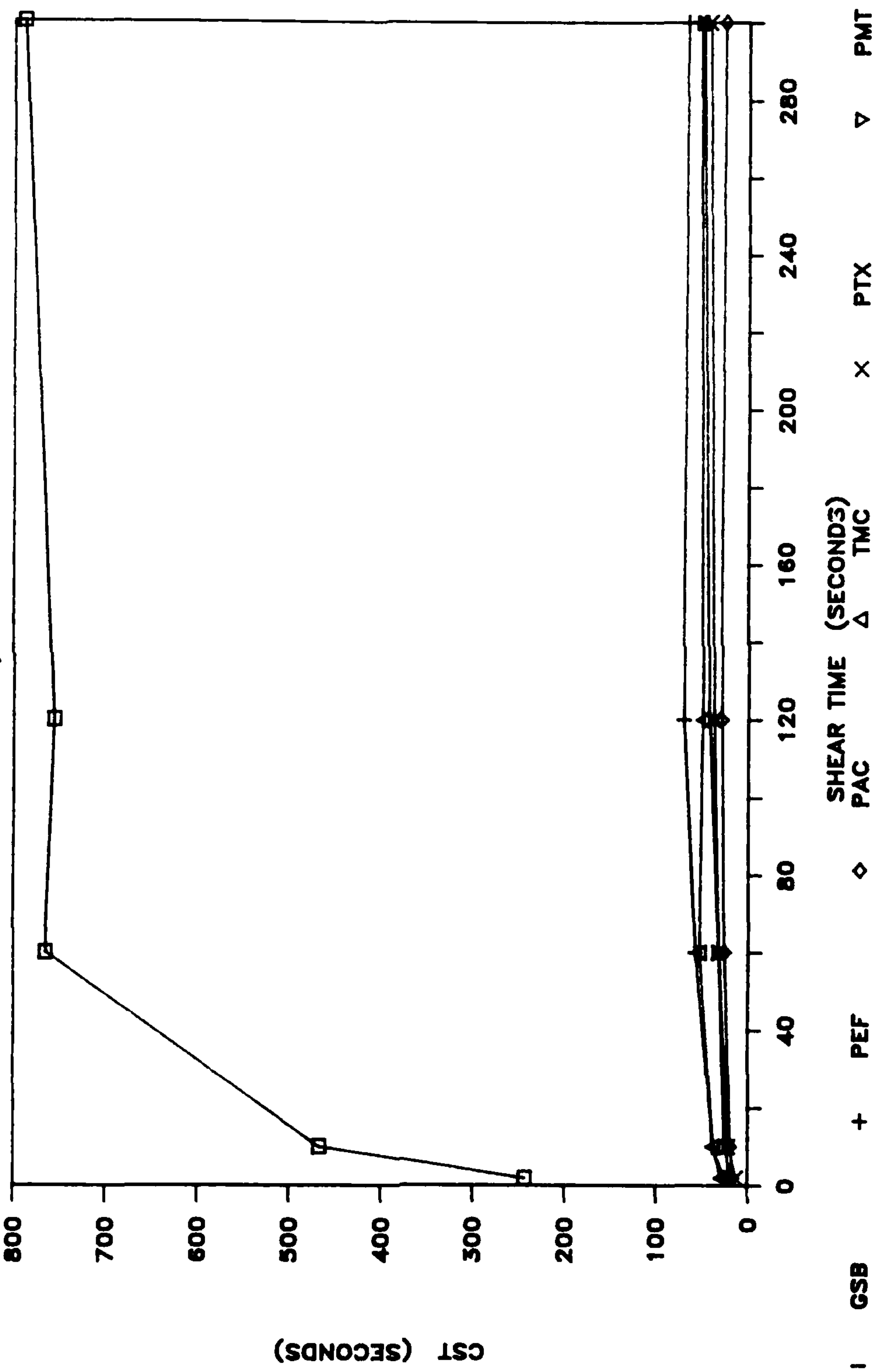


FIGURE 7. CST, 0.5% KCL

VARIED SHEAR RATE, SHEAR TIME = 120 SEC

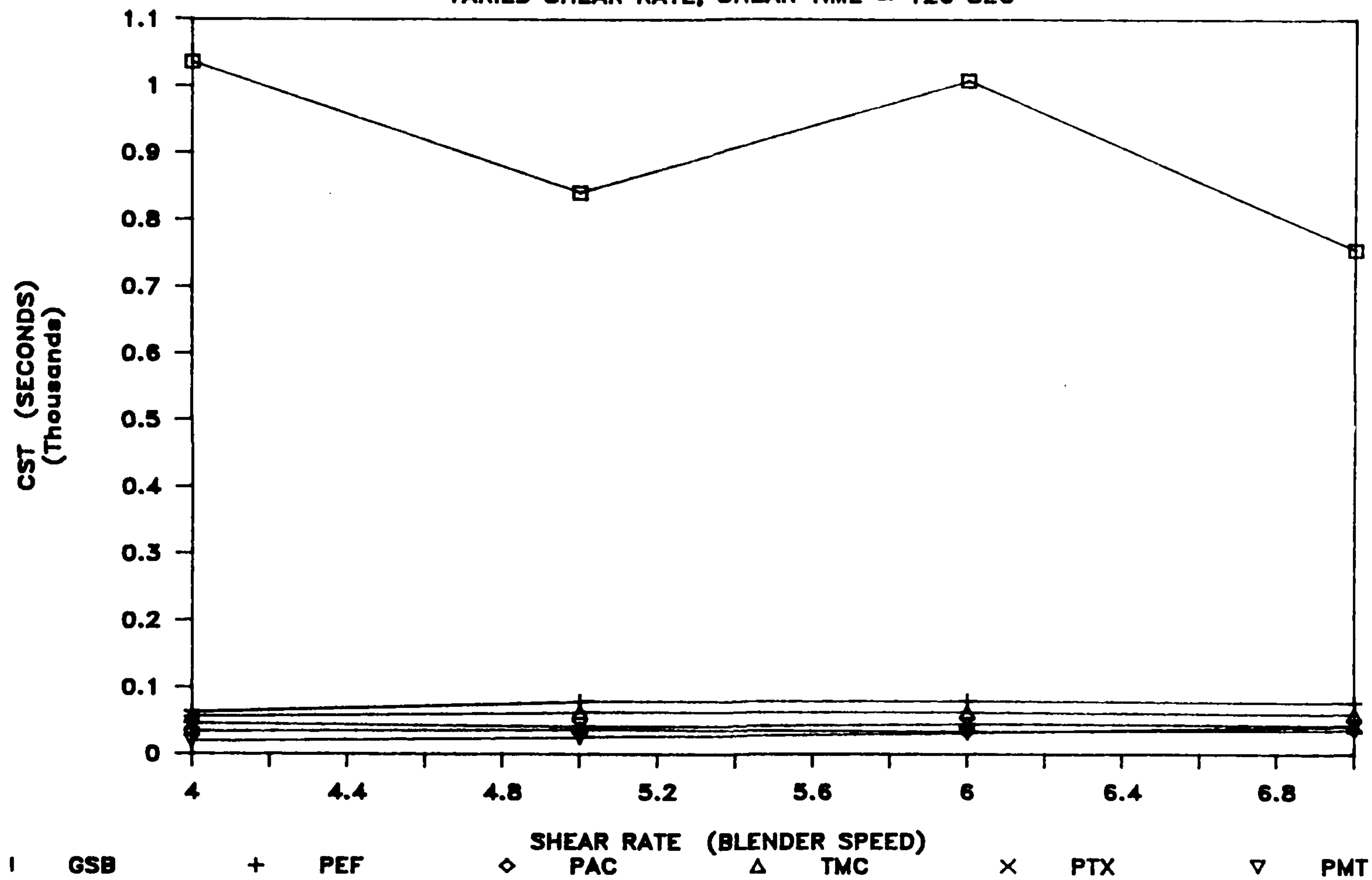


FIGURE 8. CST, 0.5% KCL

VARIED SHEAR RATE, SHEAR TIME = 120 SEC

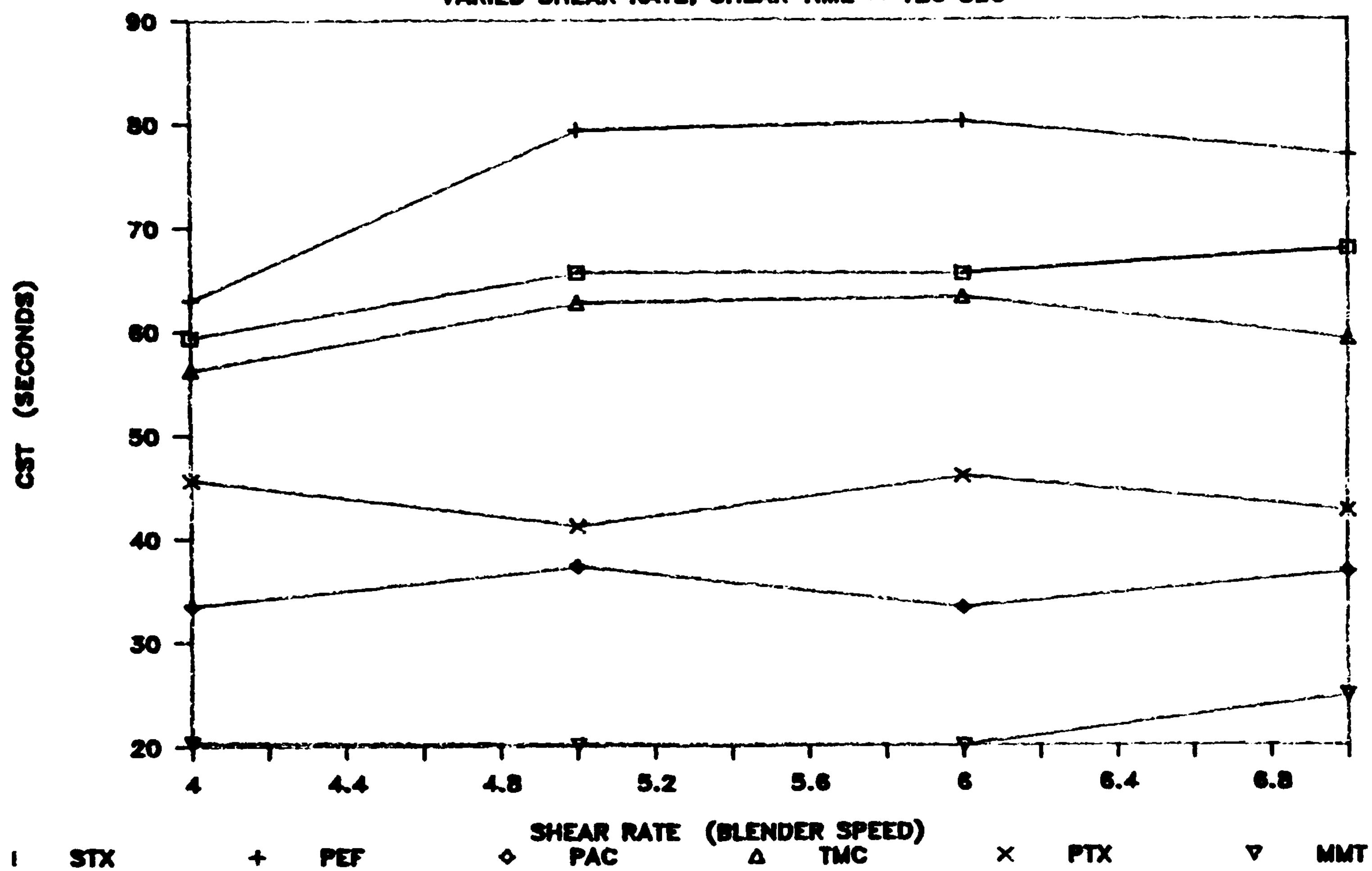


FIGURE 9. CST, 15% KCL

VARIED SHEAR TIME, BLENDER SPEED 7

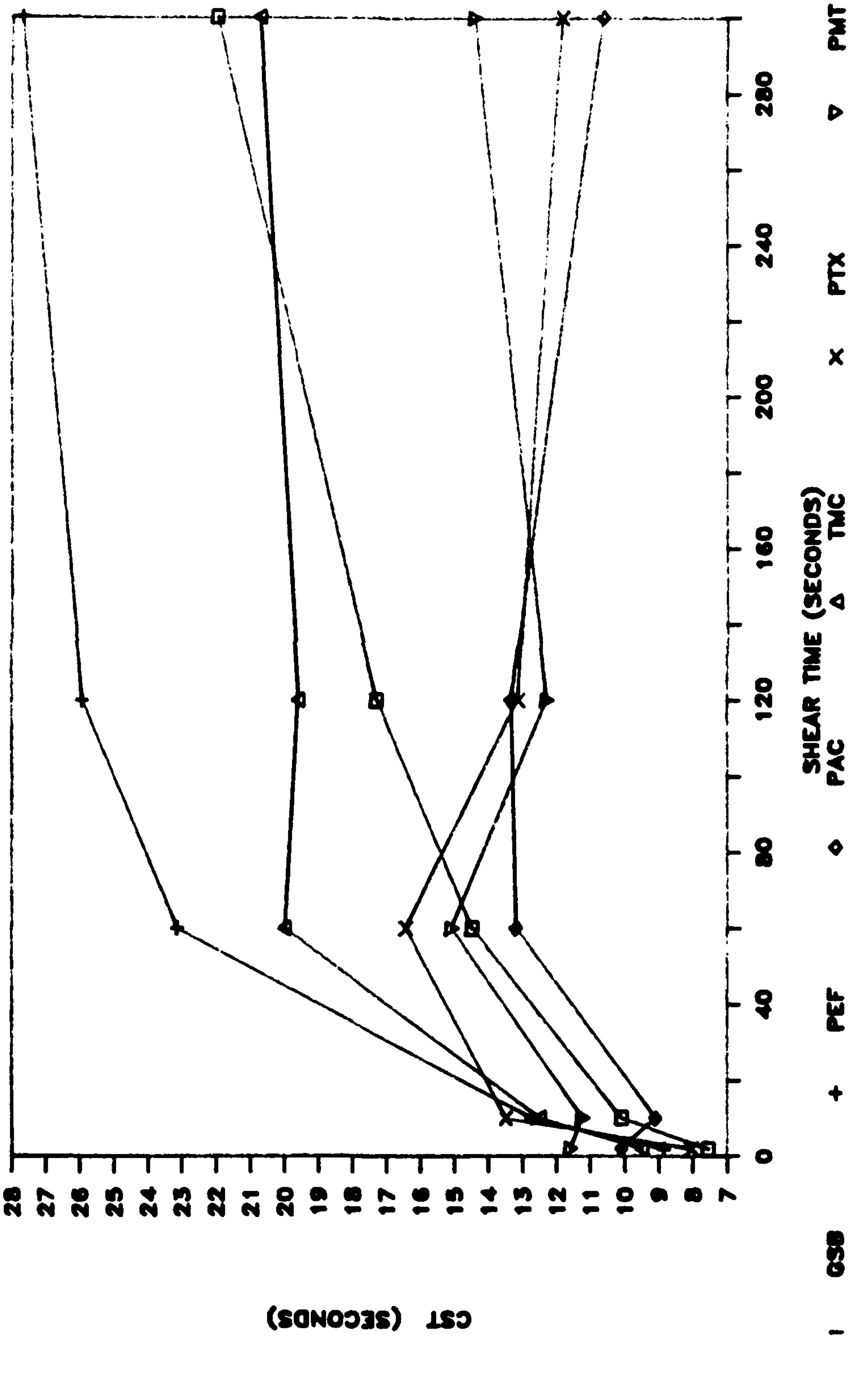


FIGURE 10. CST, 15% KCL

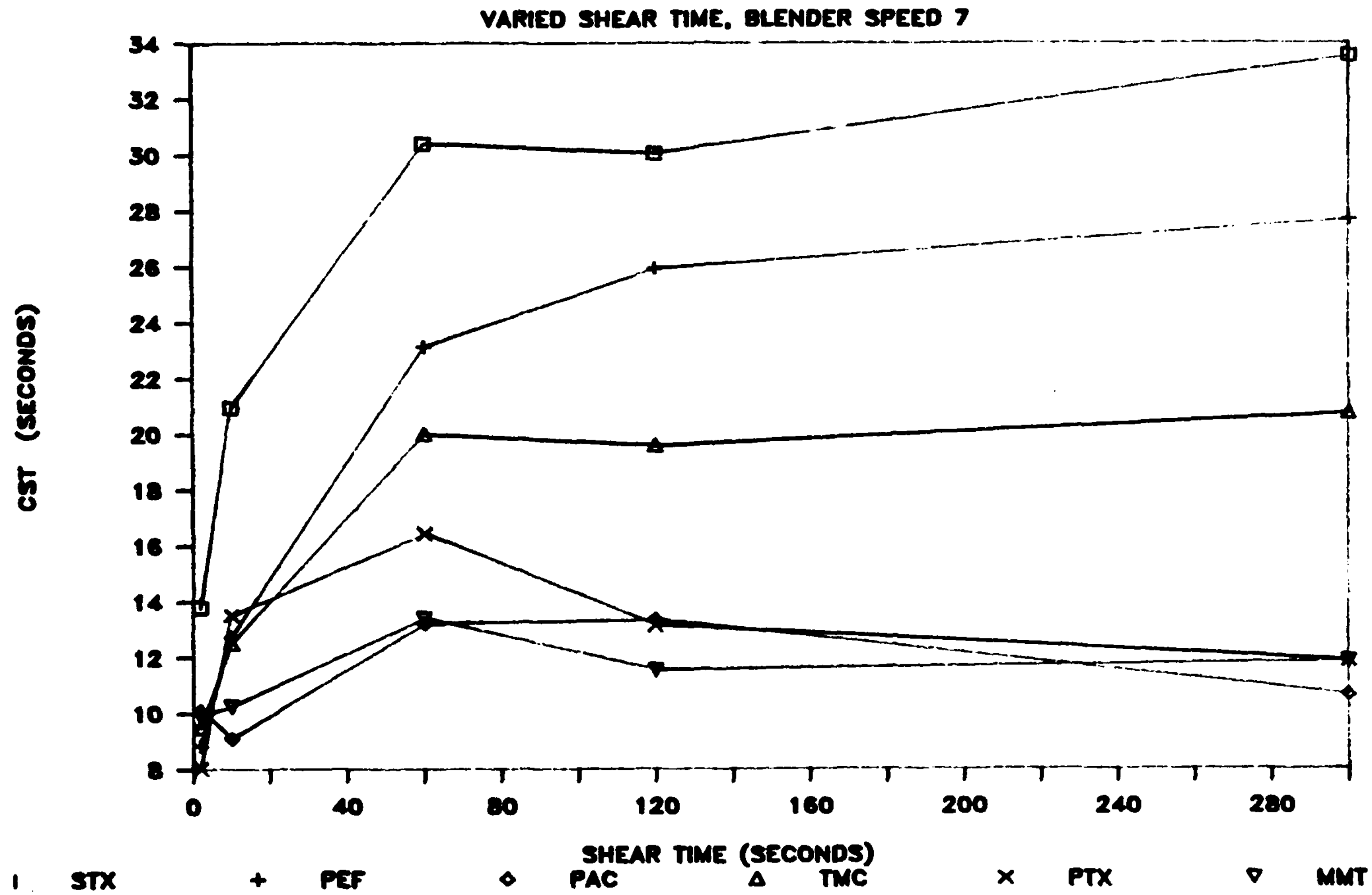


FIGURE 11. CST, 15% KCL

VARIED SHEAR RATE, TIME = 120 SEC

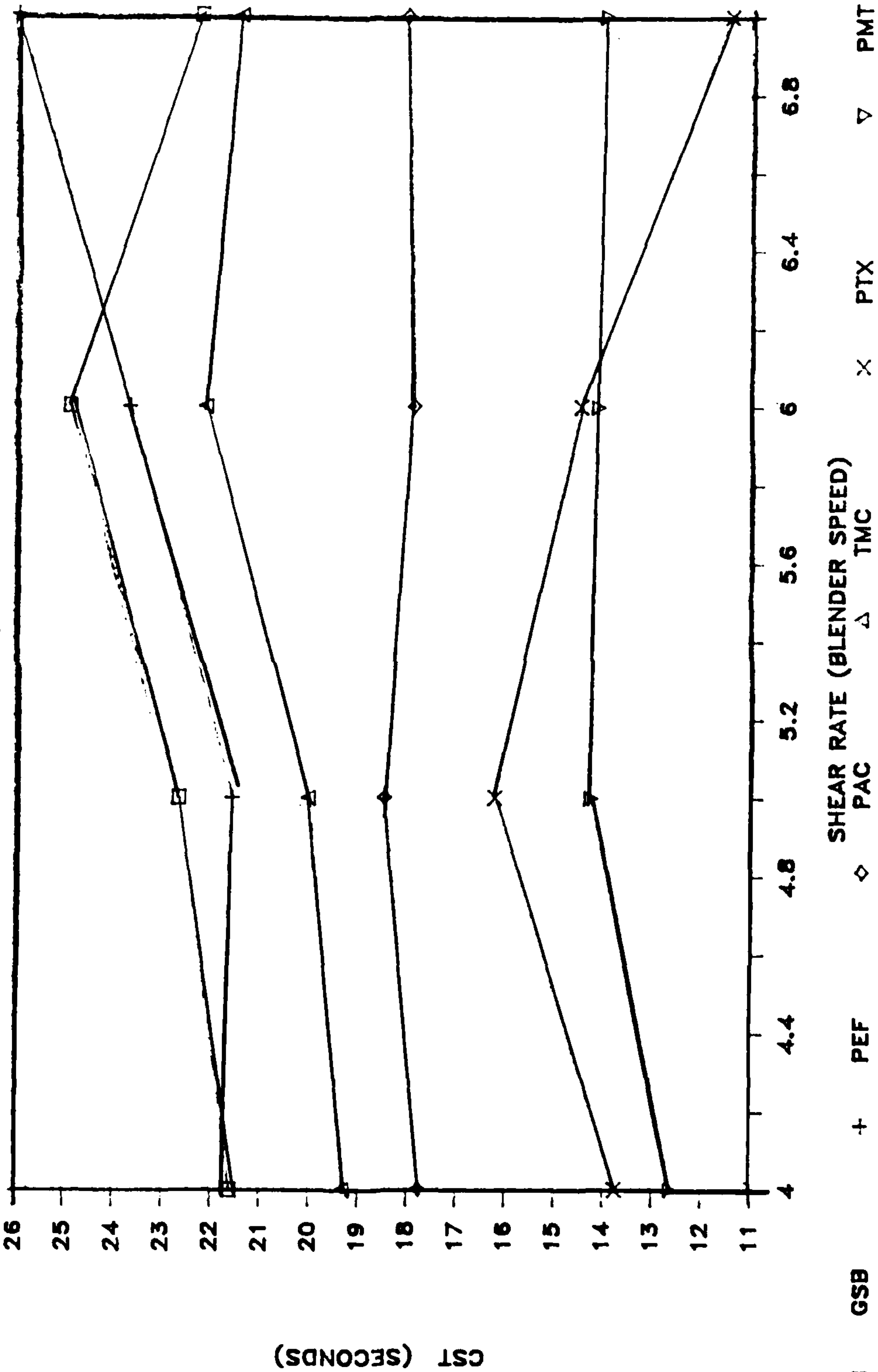


FIGURE 12. CST, 15% KCL

VARIED SHEAR RATE, TIME = 120 SEC

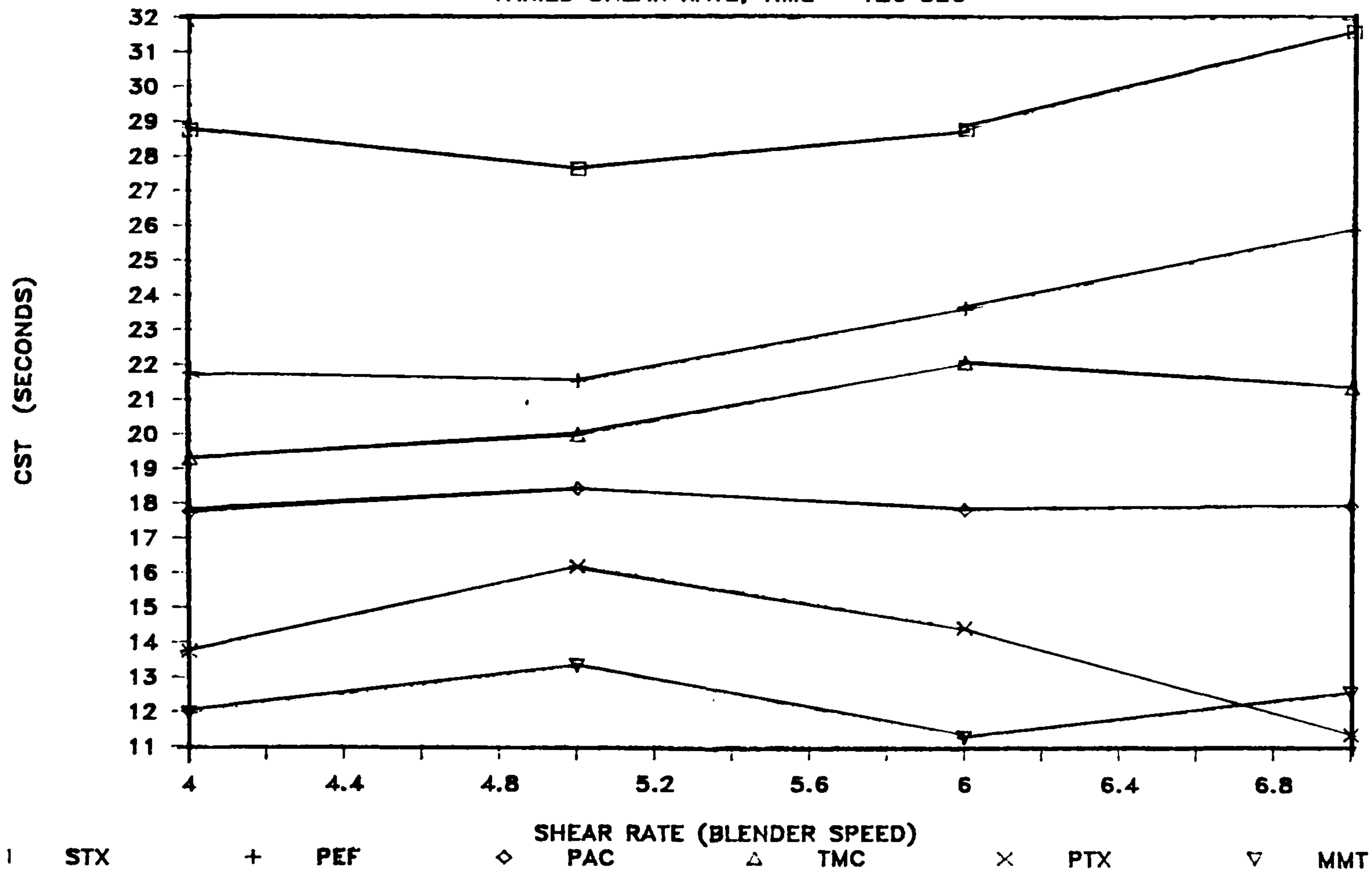


FIGURE 13. CST, GOLD SEAL BENTONITE

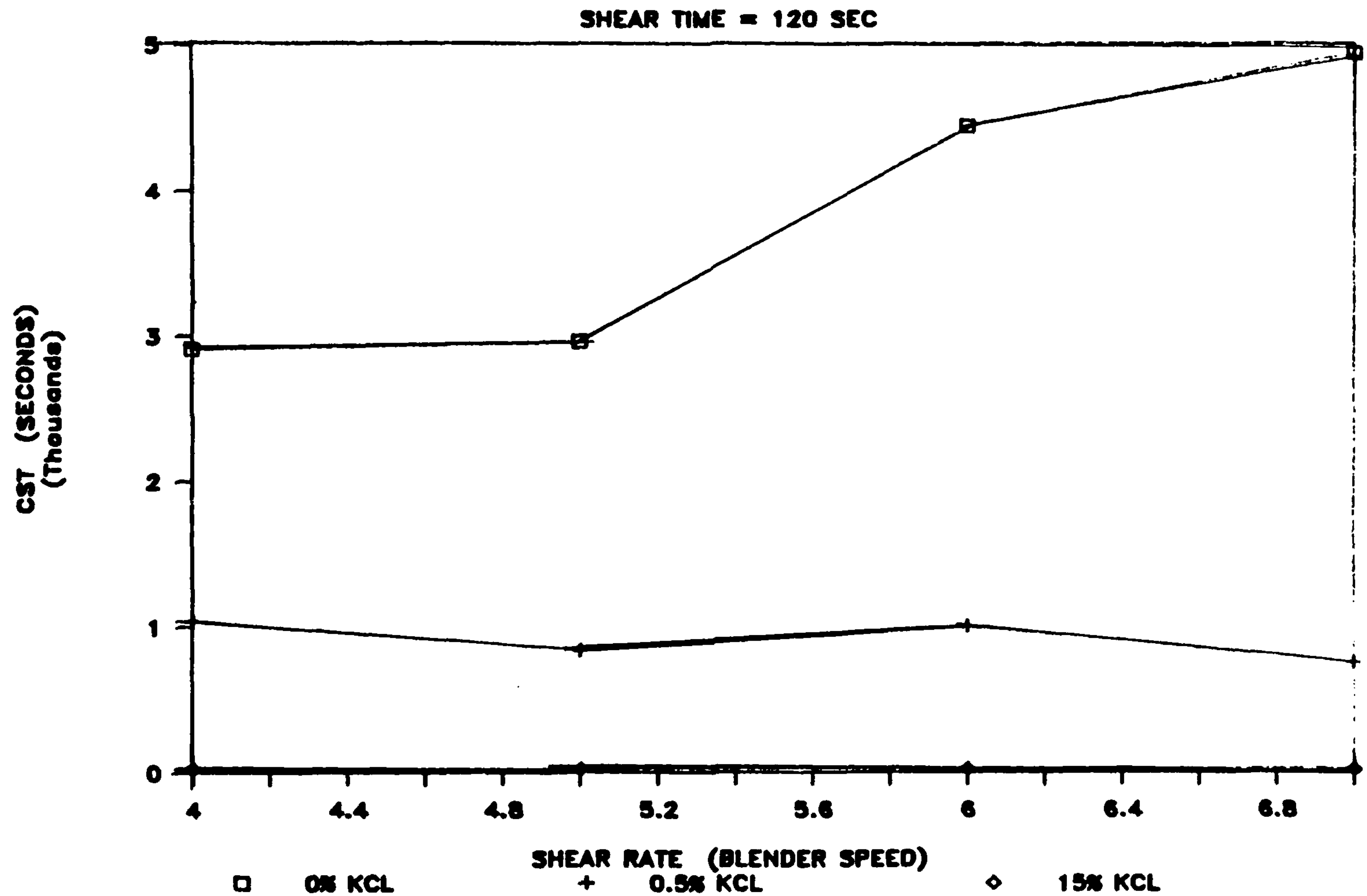


FIGURE 14. CST, PHILLIPS EKOFISK

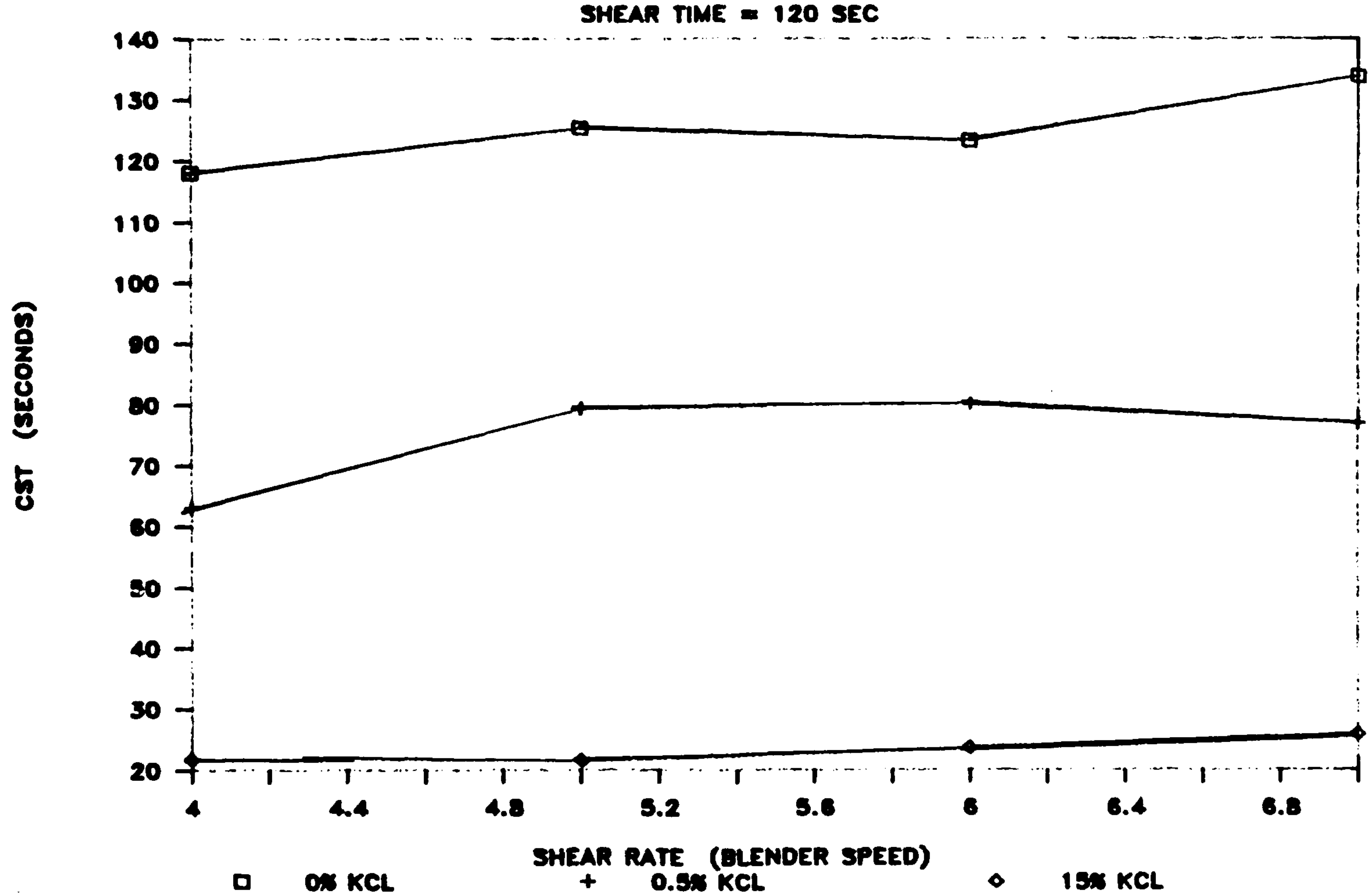


FIGURE 15. CST, PHILLIPS ANDREWS CO.

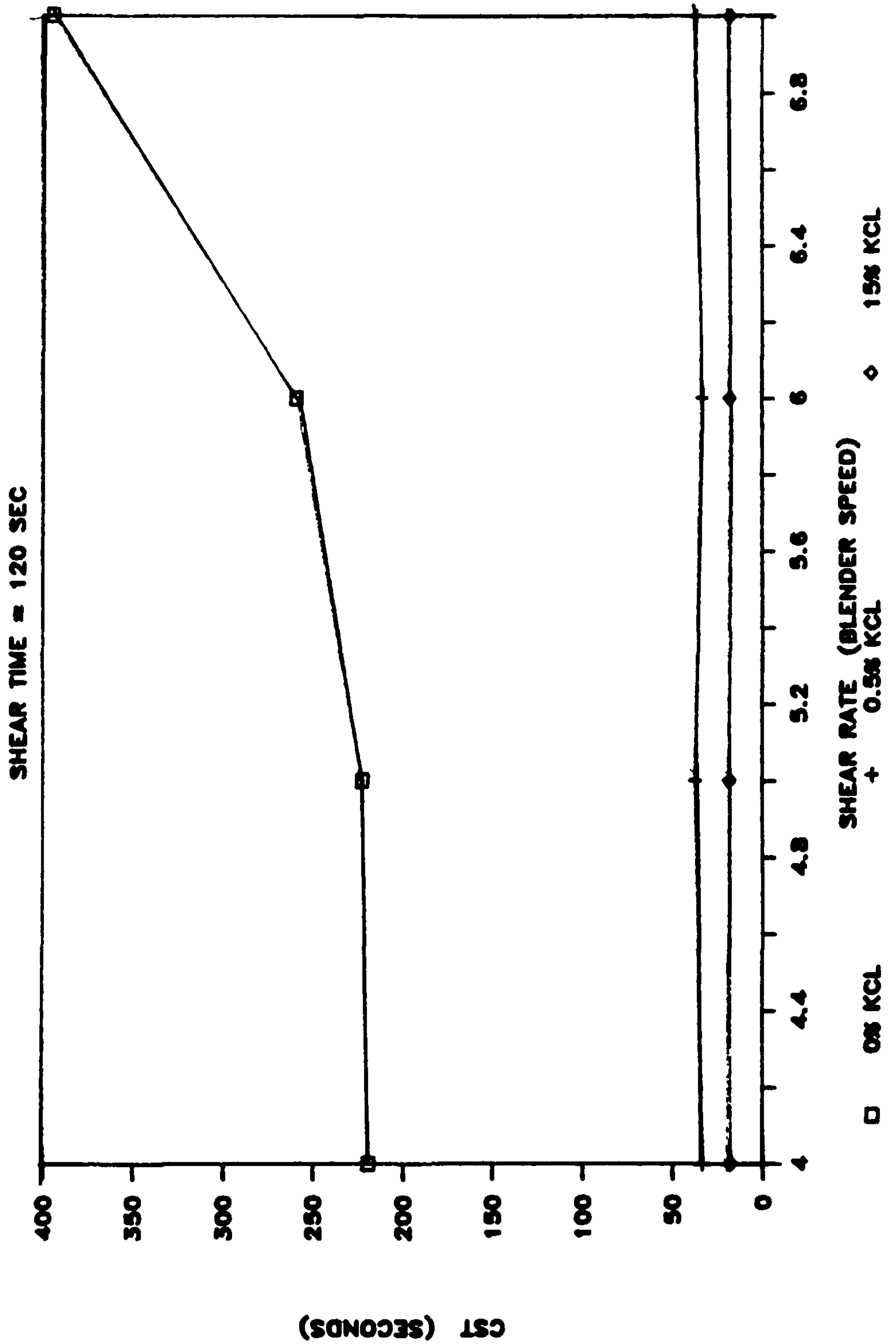


FIGURE 16. CST, TEXACO MISS. CANYON

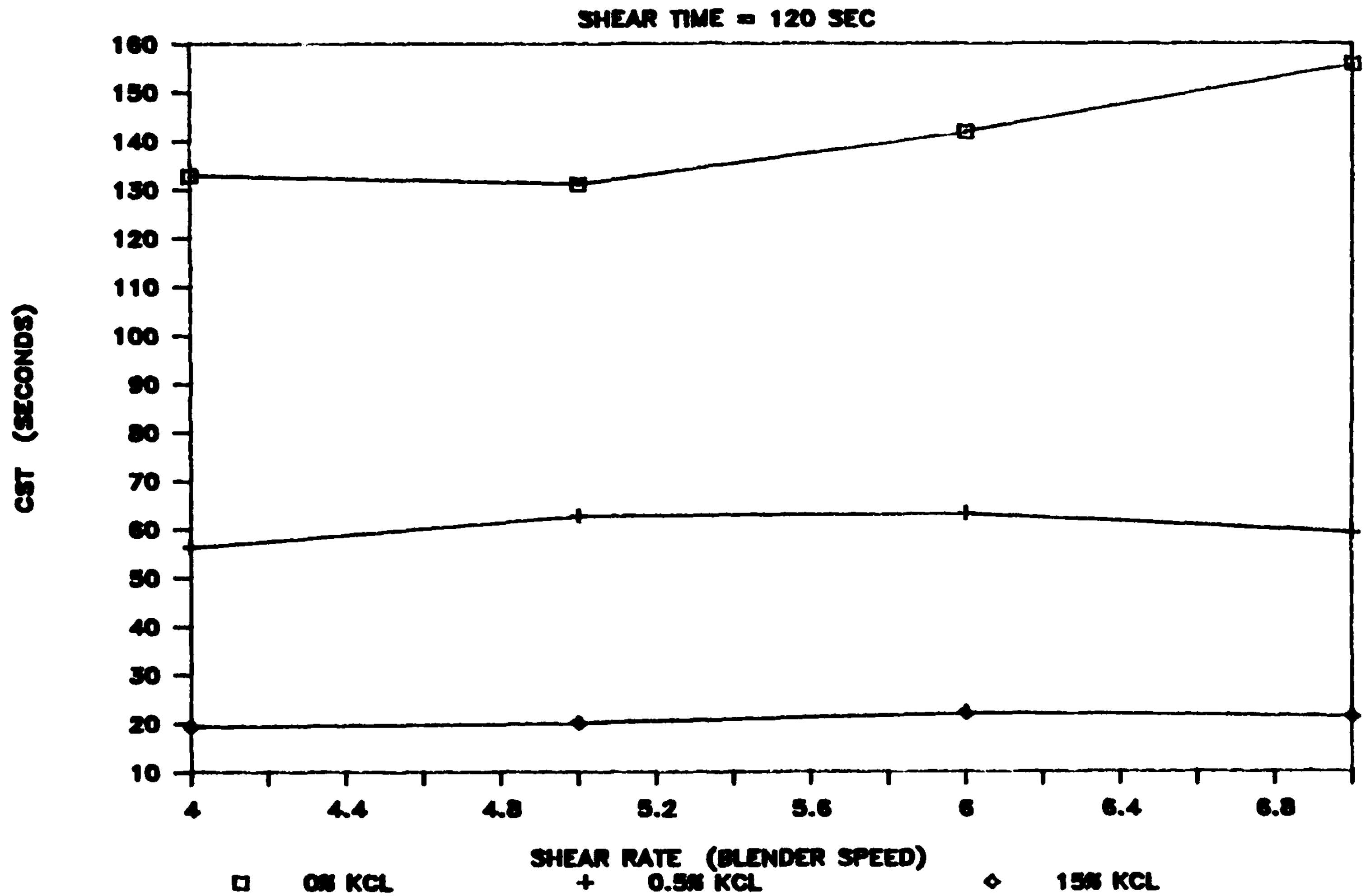


FIGURE 17. CST, PIERRE TEXACO

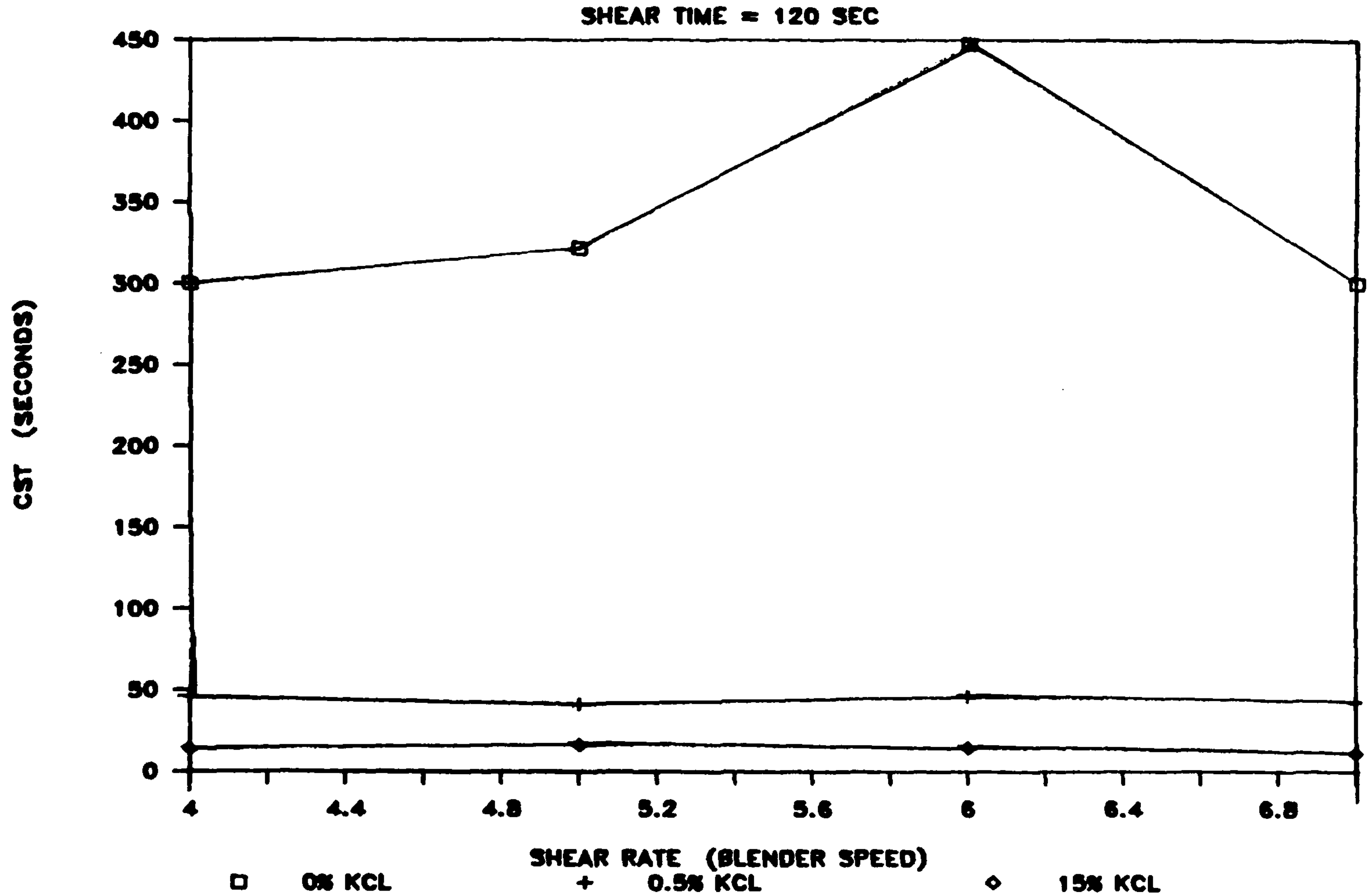


FIGURE 18. CST, PIERRE MUDTECH

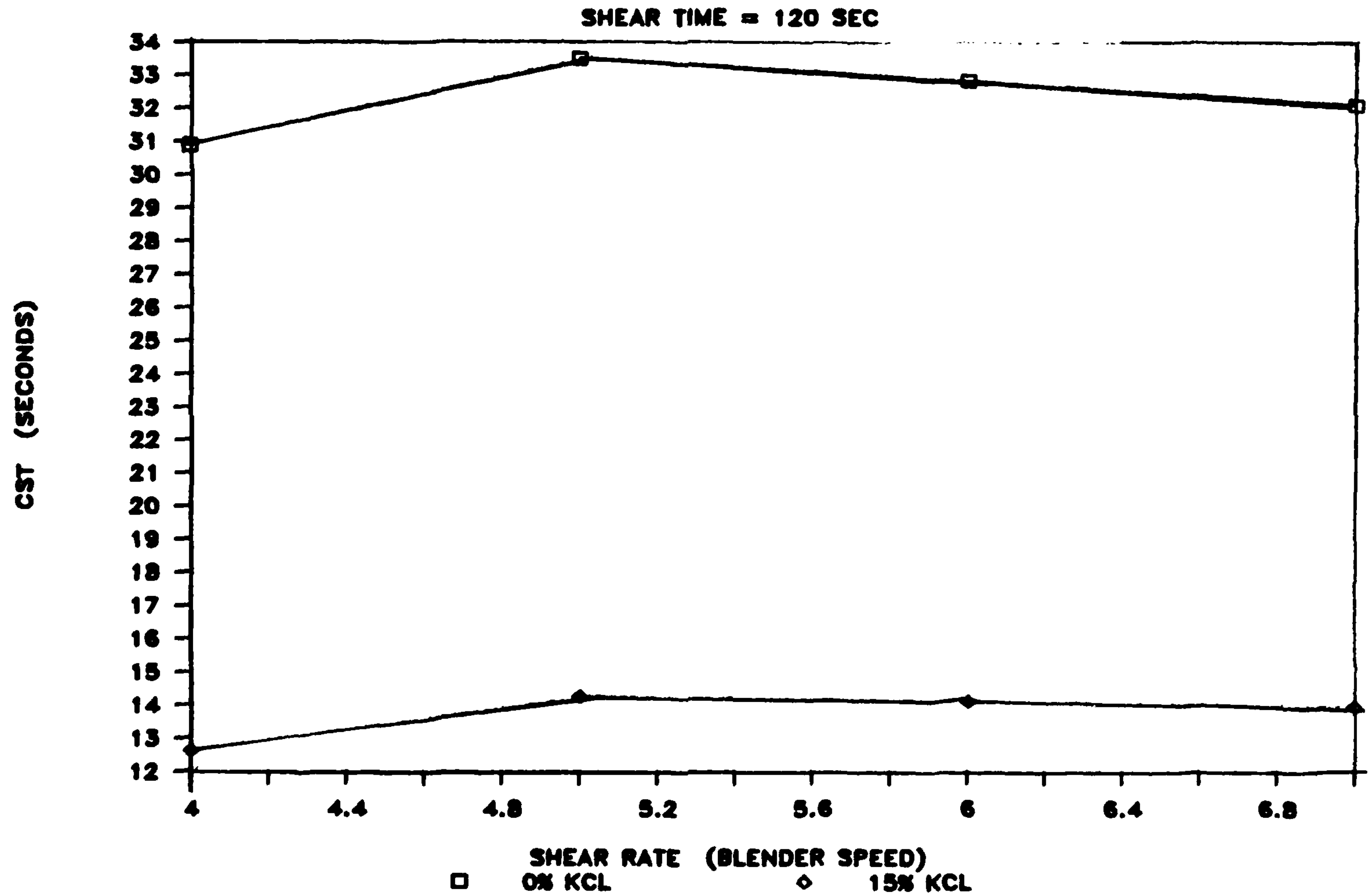


FIGURE 19. CST, MANCOS MUDTECH

SHEAR TIME = 120 SEC

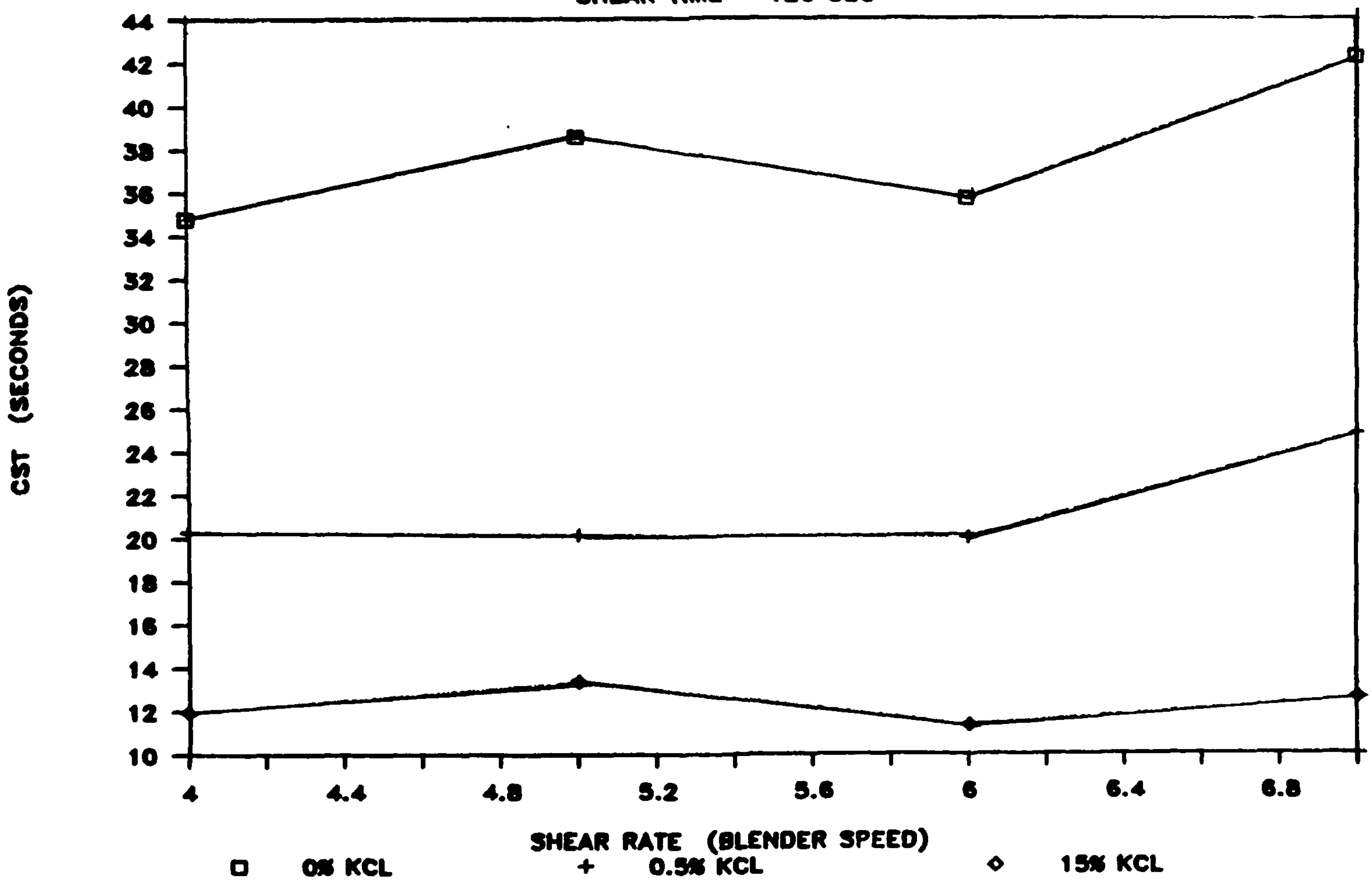


FIGURE 20. CST, STANDARD TEXAS

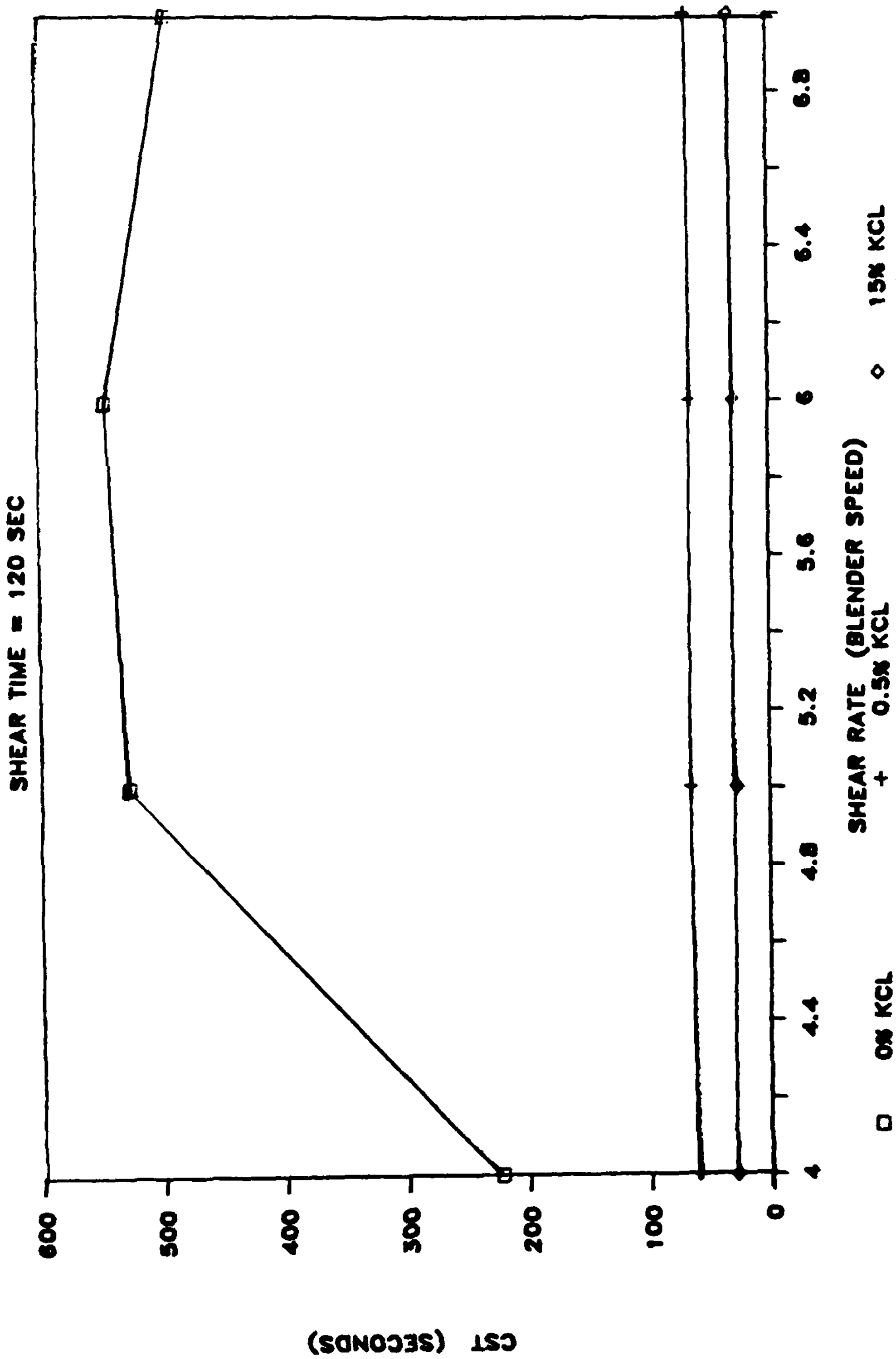


FIGURE 21. CST, GOLD SEAL BENTONITE

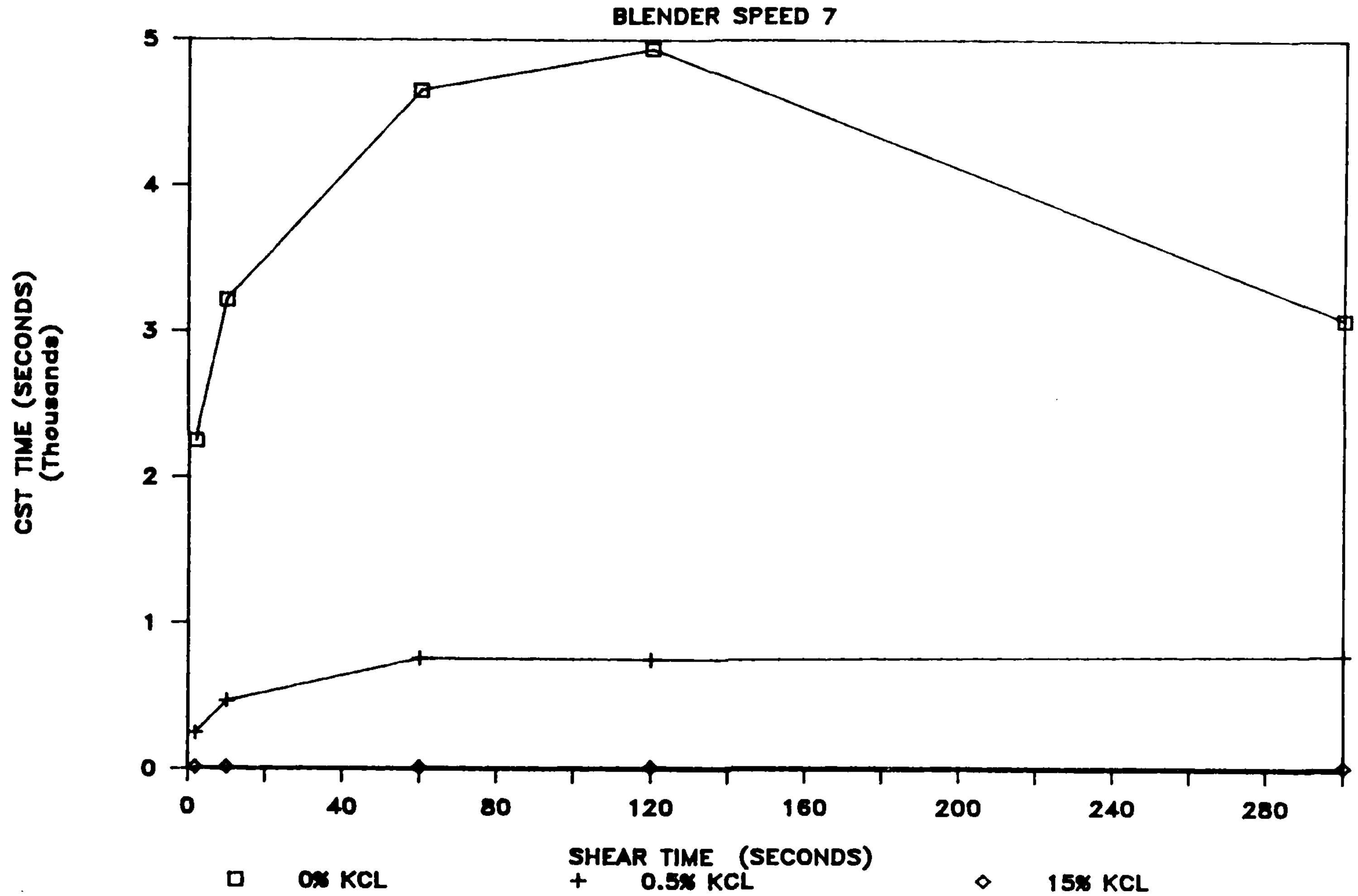


FIGURE 22. CST, PHILLIPS EKOFISK

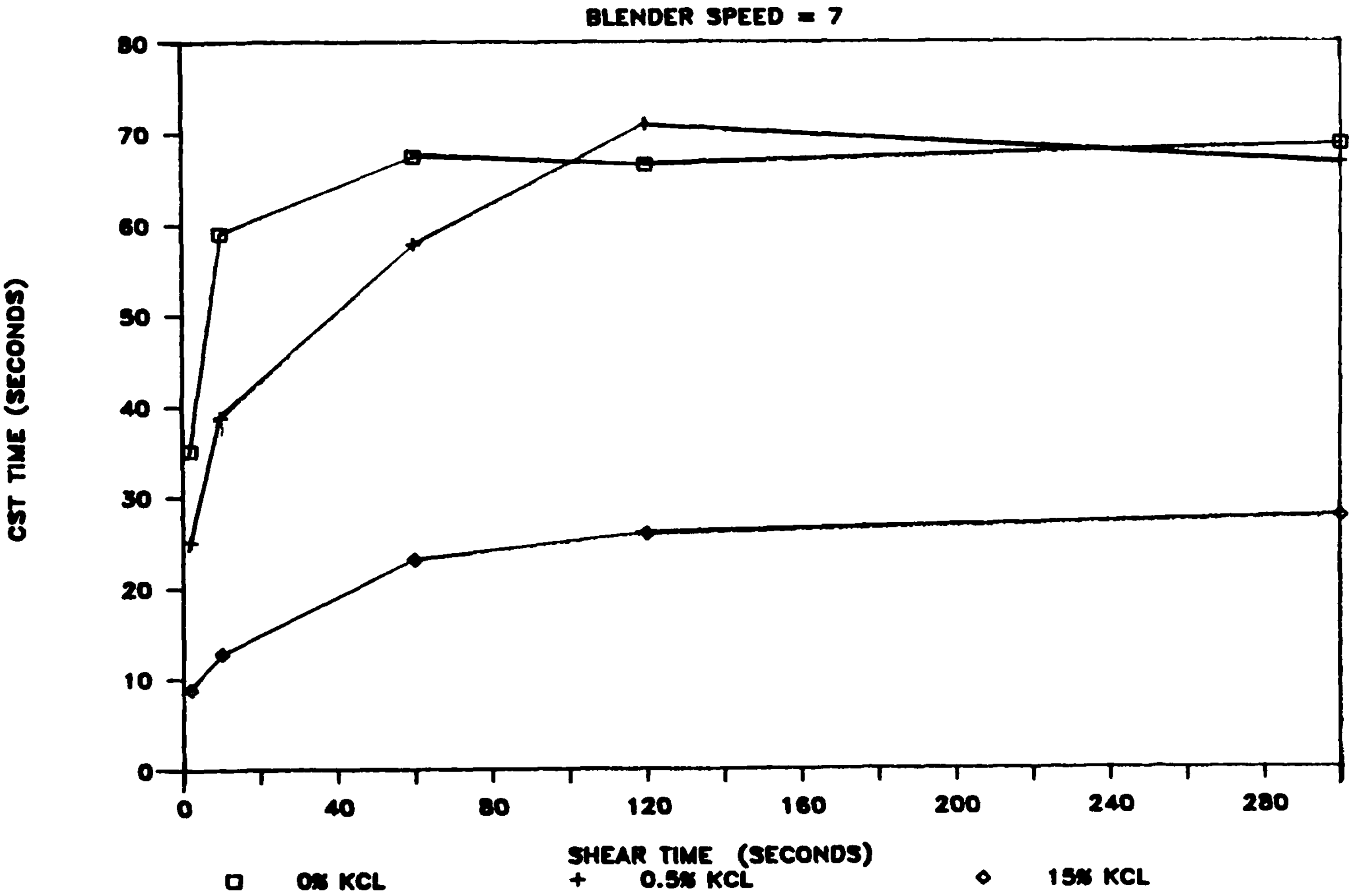


FIGURE 23. CST, PHILLIPS ANDREWS CO.

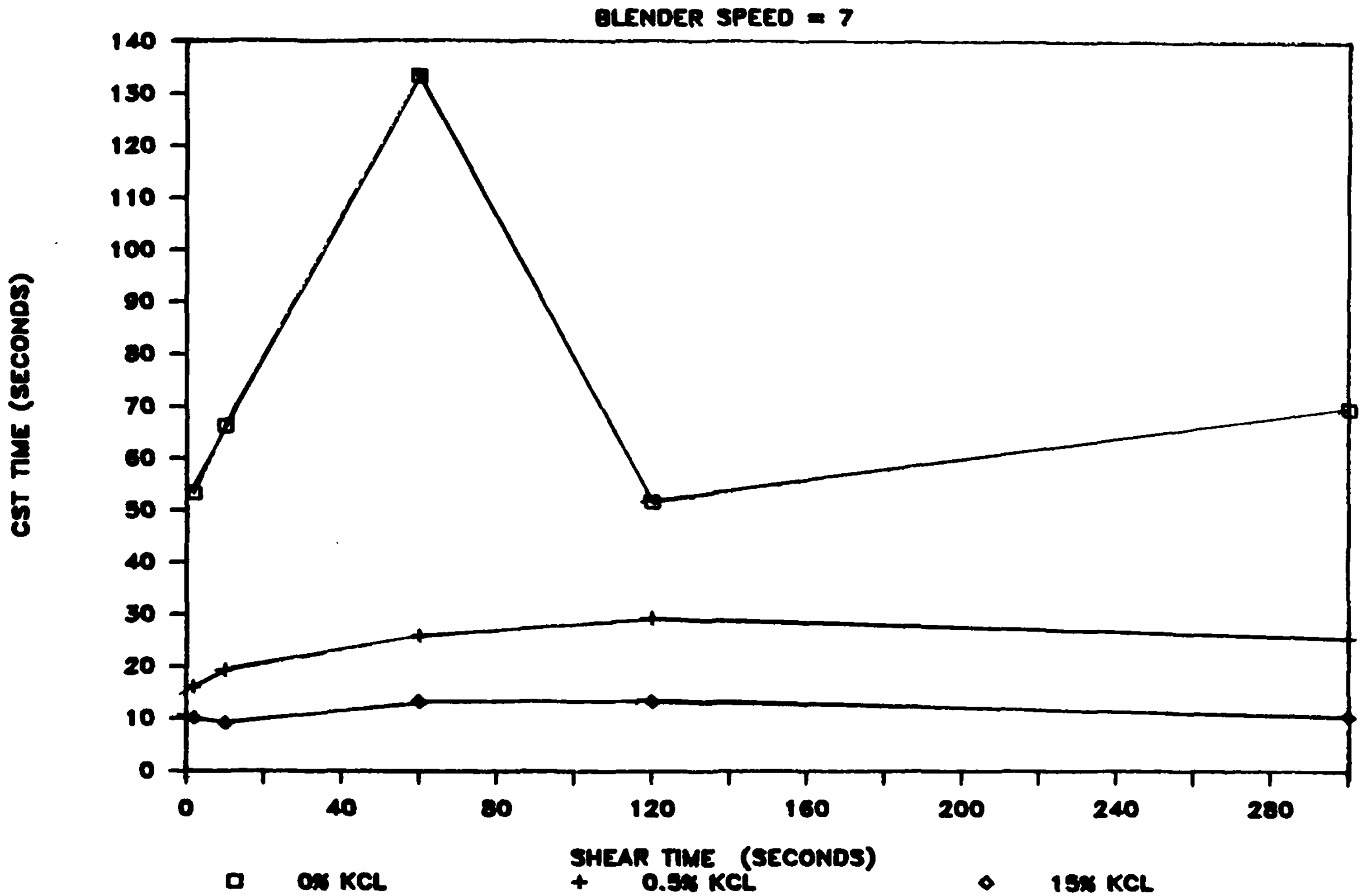


FIGURE 24. CST, TEXACO MISS. CANYON

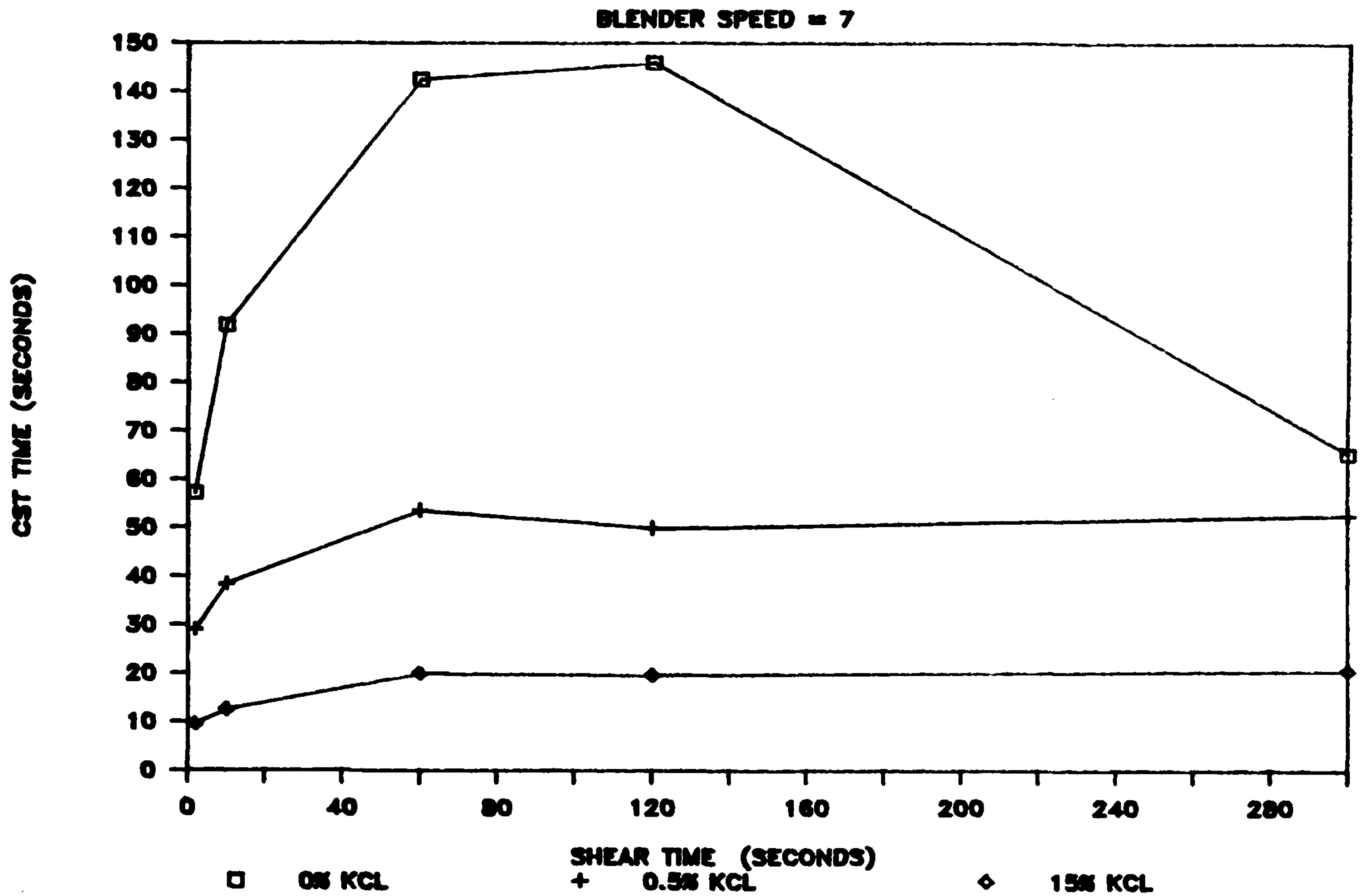


FIGURE 25. CST, PIERRE TEXACO

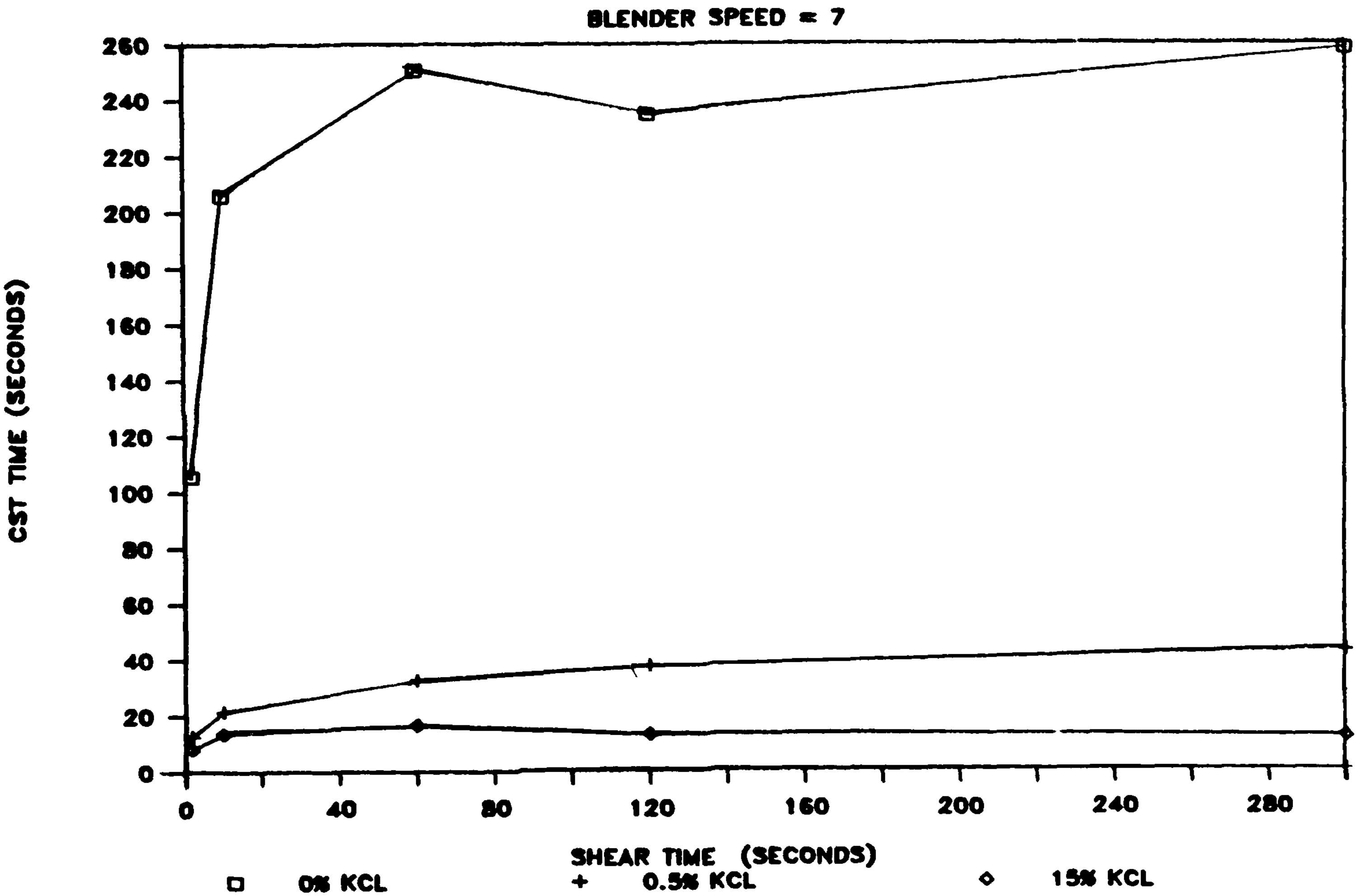


FIGURE 26. CST, PIERRE MUDTECH

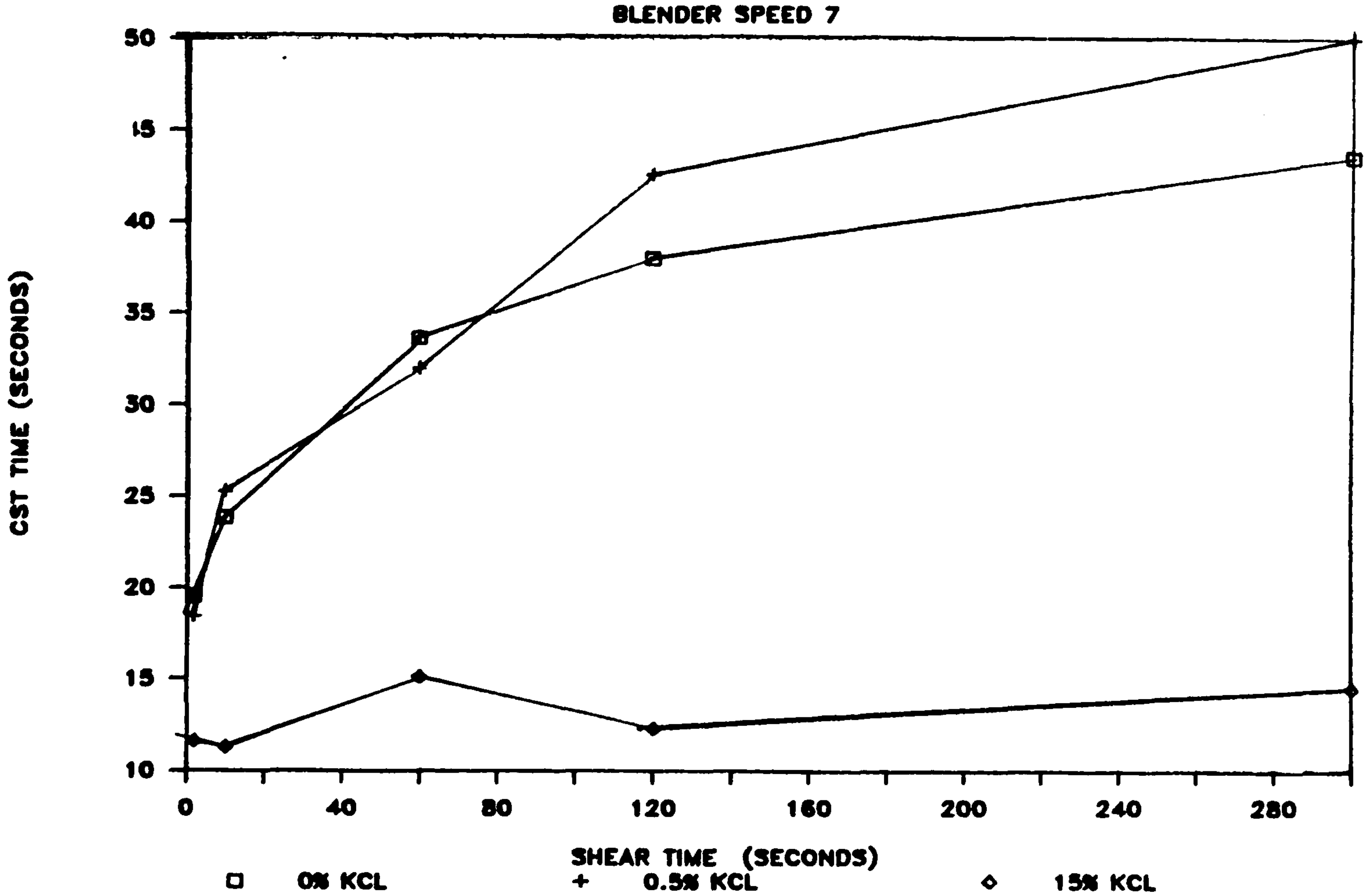


FIGURE 27. CST, MANCOS MUDTECH

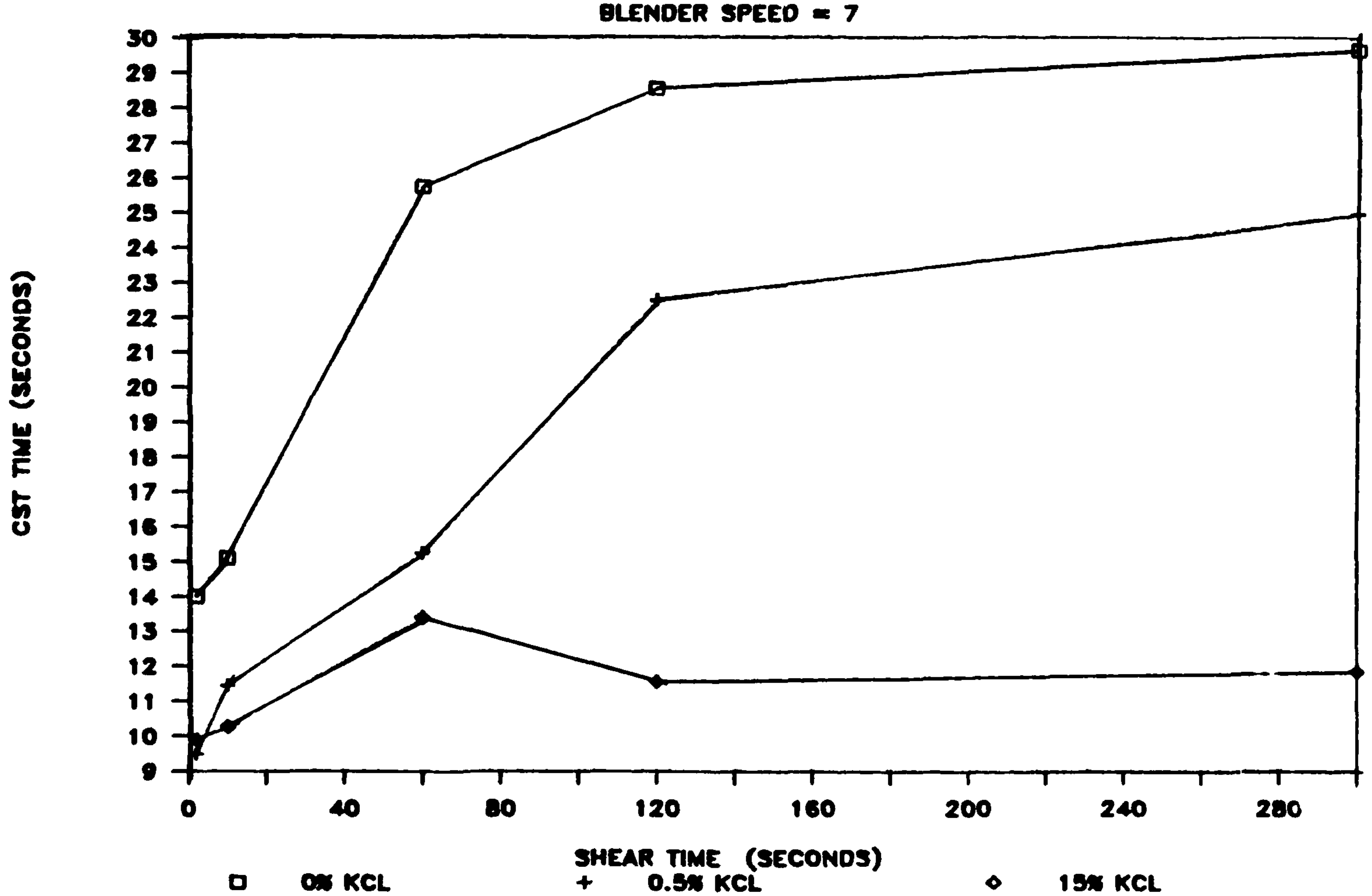


FIGURE 28. CST, STANDARD TEXAS

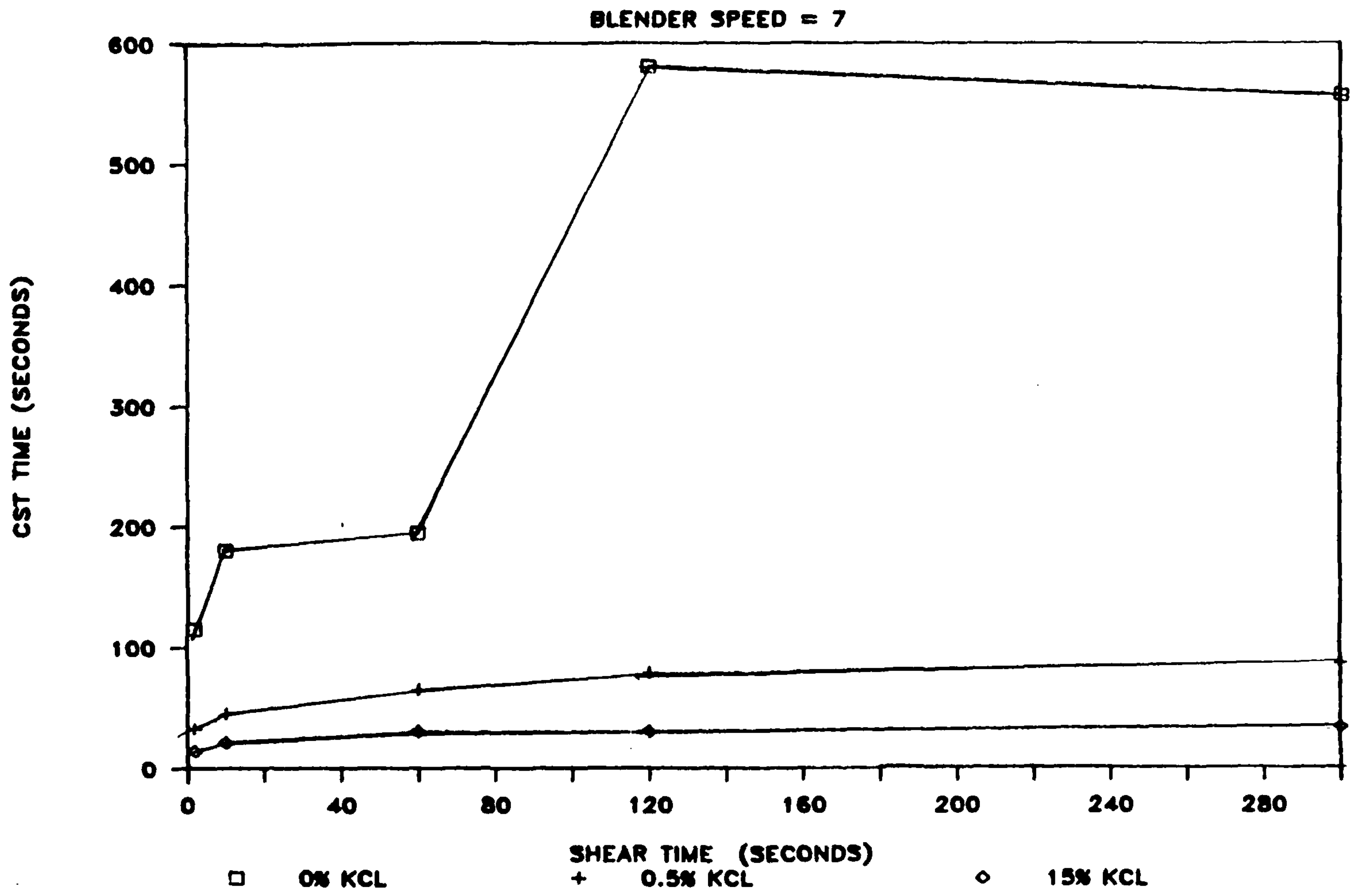


FIGURE 29. CST, 0% KCL

VARIED SHEAR TIME, BLENDER SPEED 7

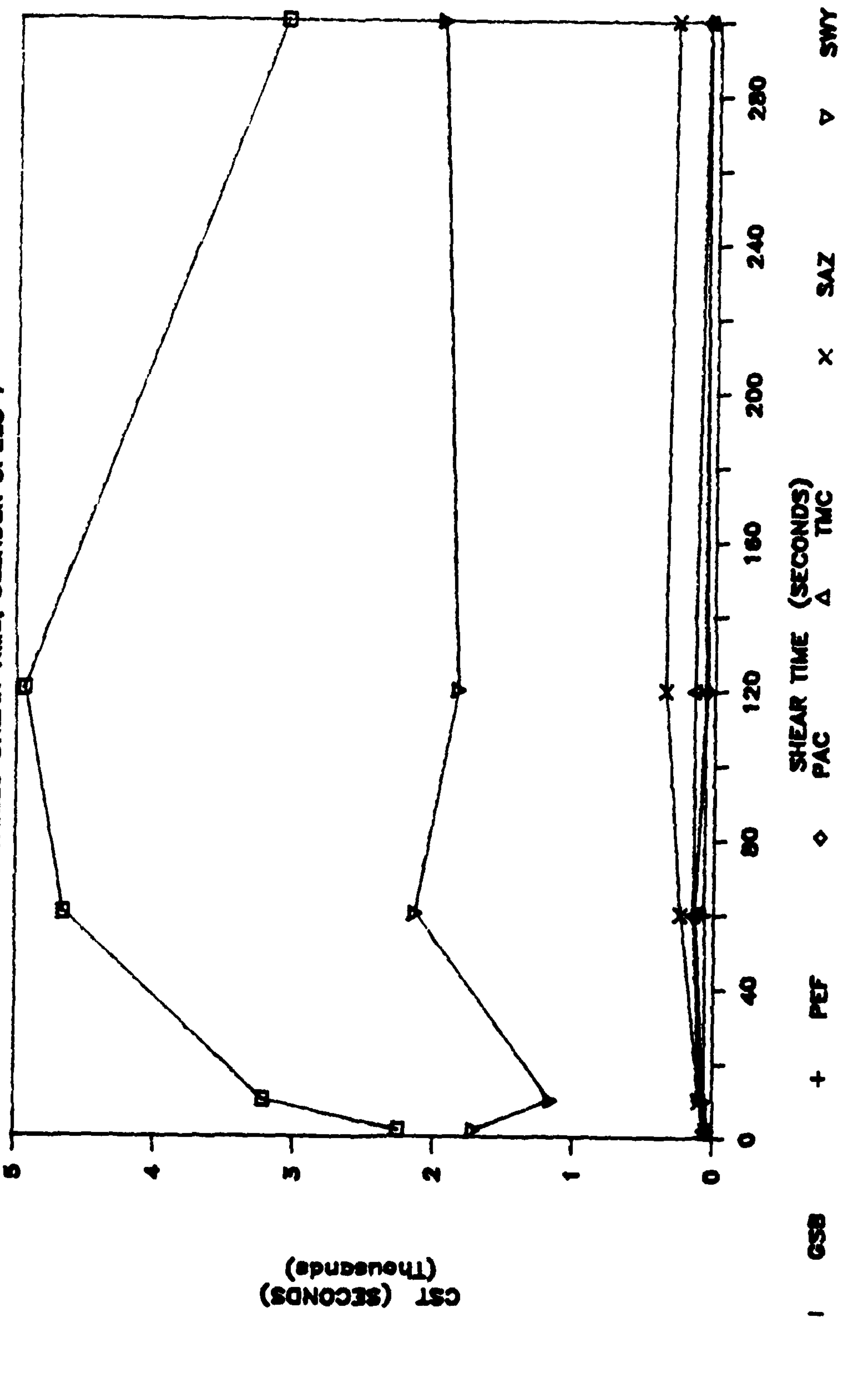


FIGURE 30. CST, 0% KCL

VARIED SHEAR TIME, BLENDER SPEED 7

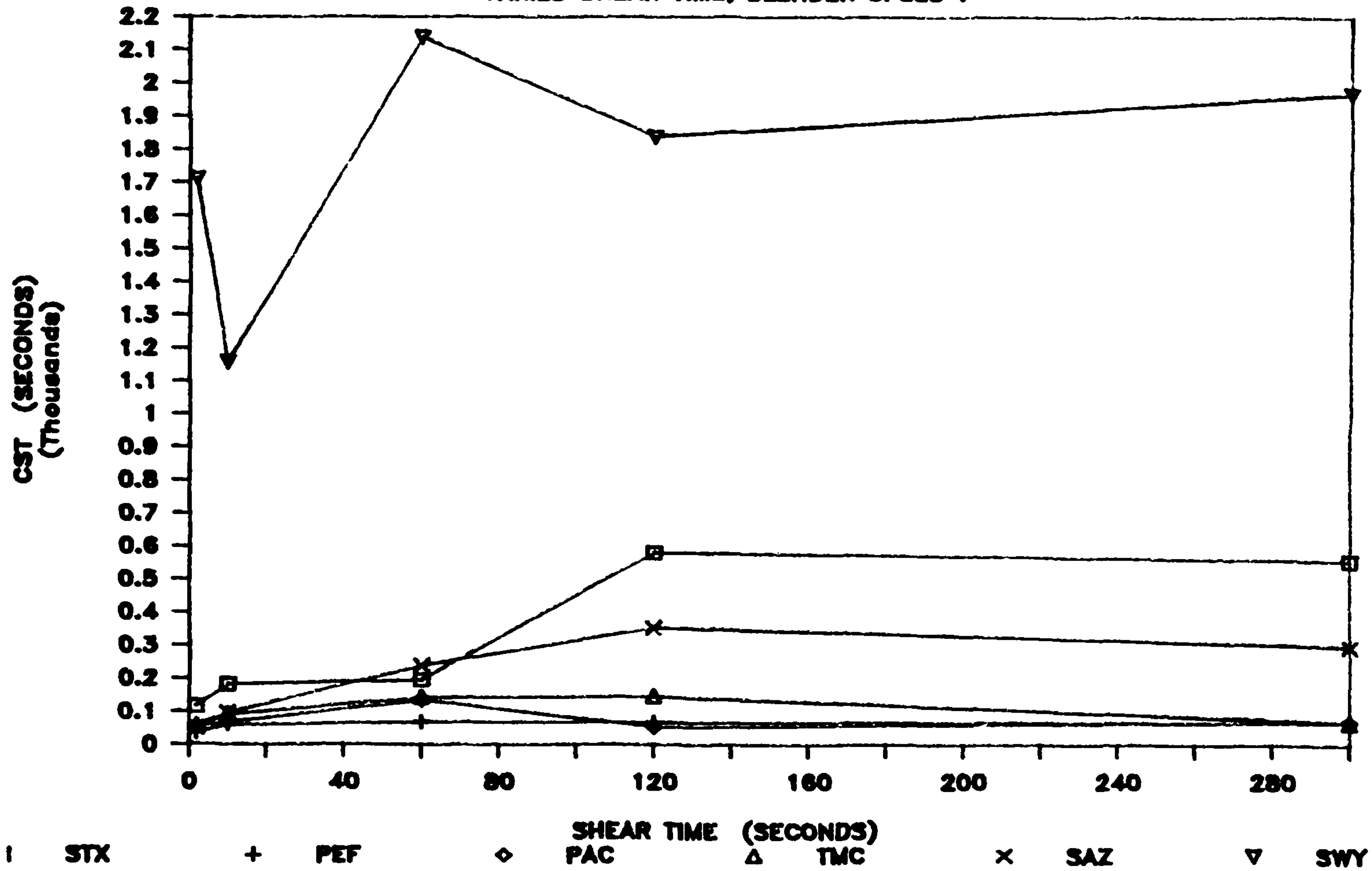


FIGURE 31. CST, 0%KCL

VARIED SHEAR RATE, TIME = 120 SEC

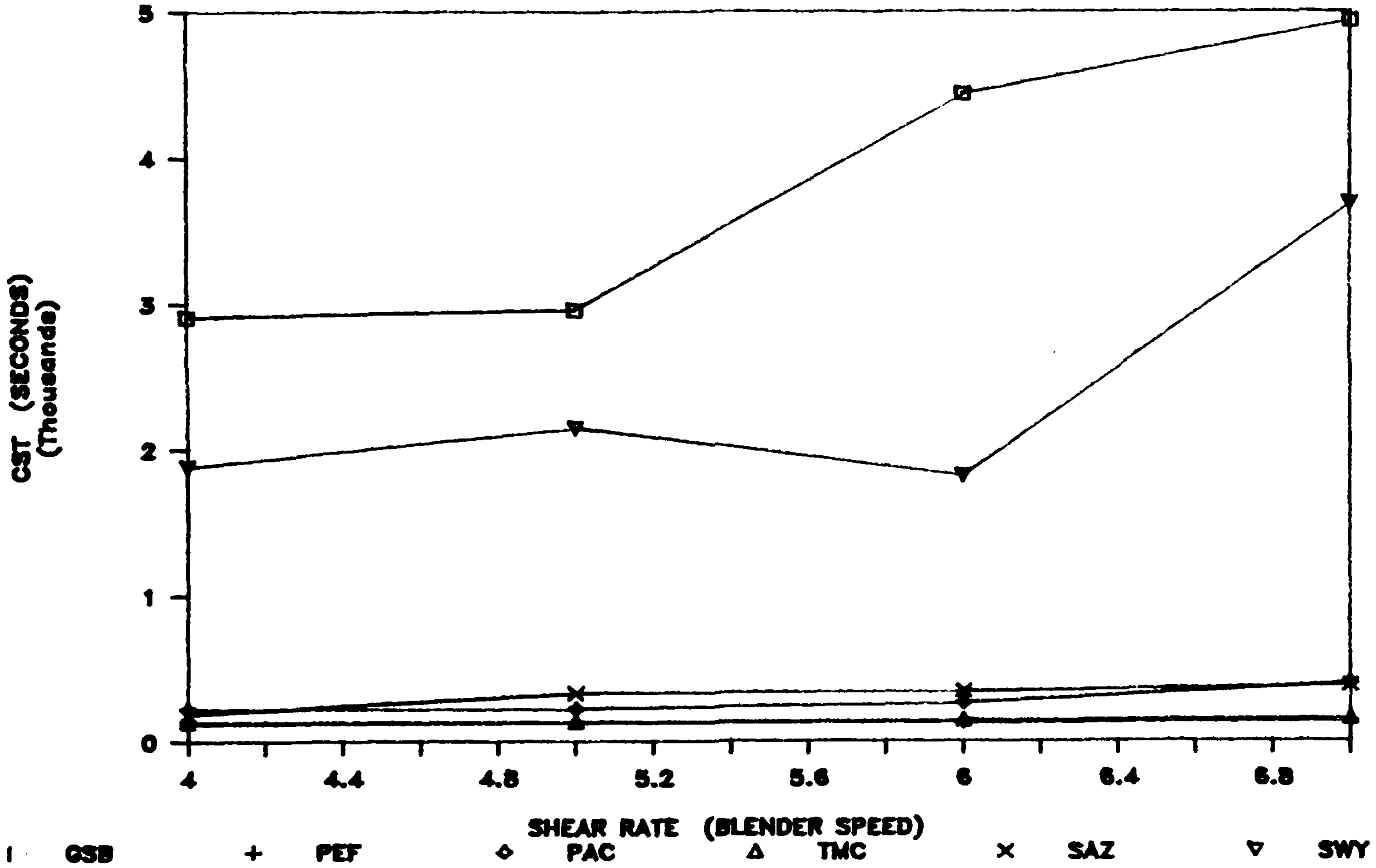


FIGURE 32, CST, 0%KCL

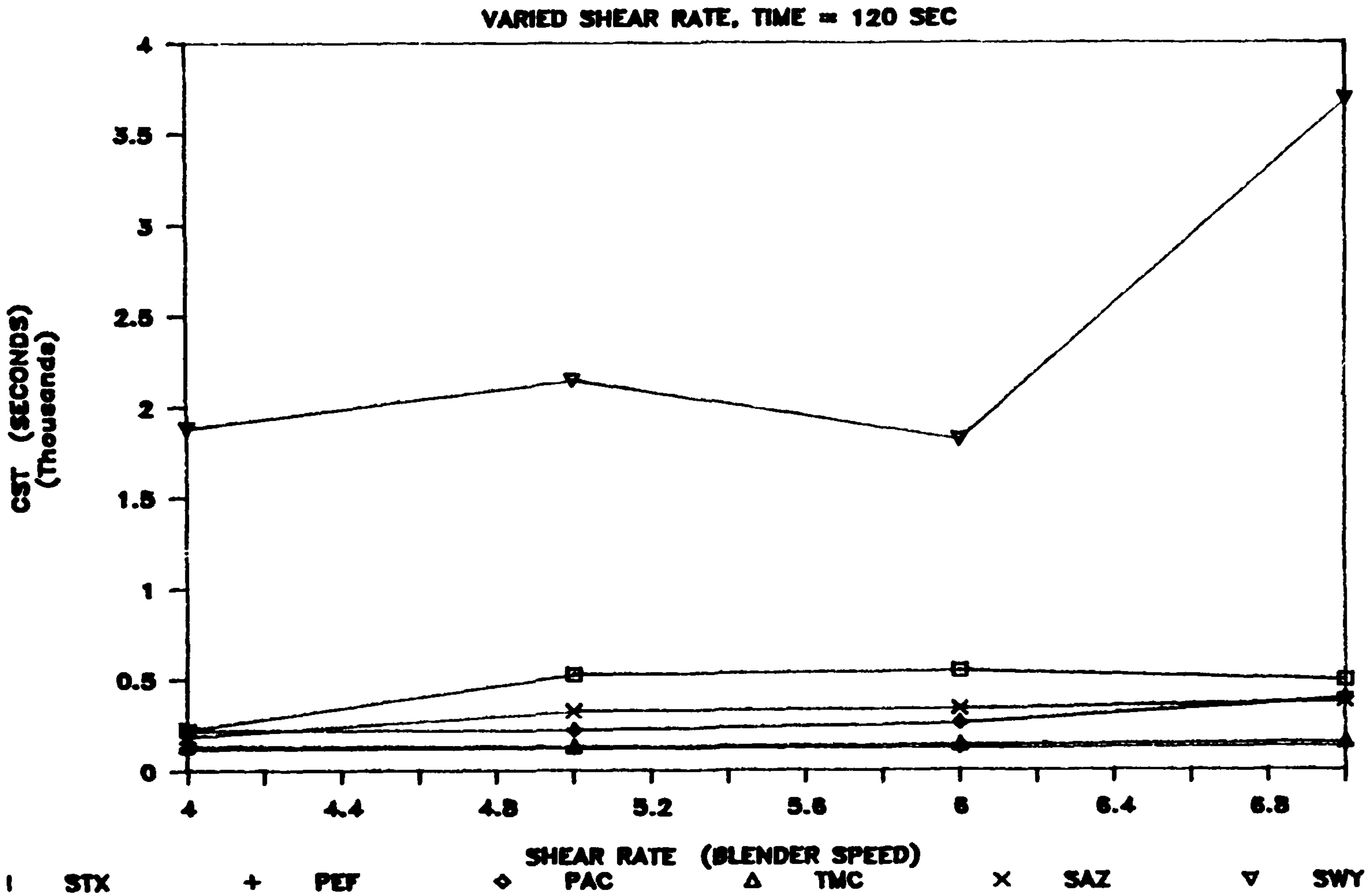


FIGURE 33. CST, 0.5% KCL

VARIED SHEAR TIME, BLENDER SPEED = 7

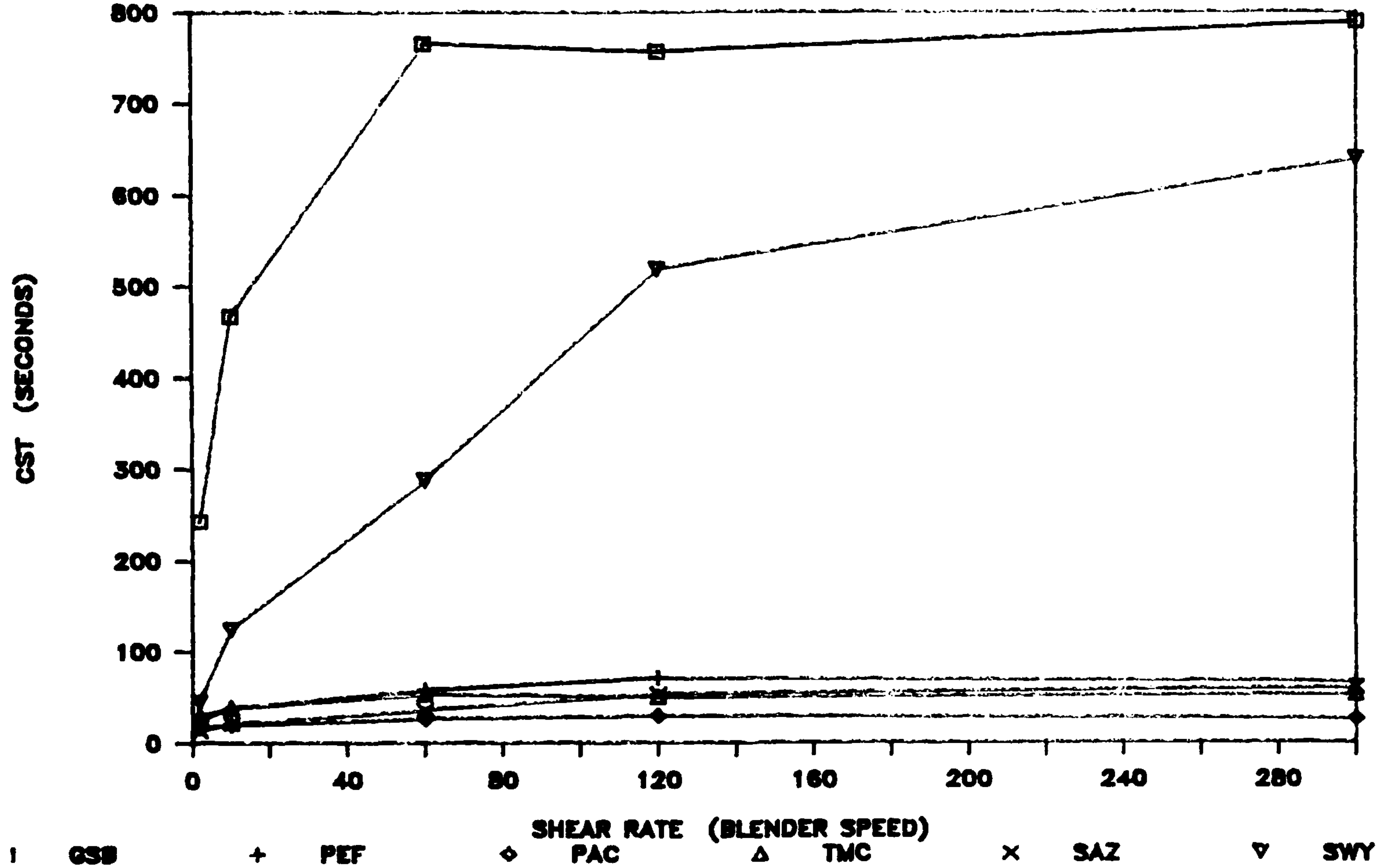


FIGURE 34. CST, 0.5% KCL

VARIED SHEAR TIME, BLENDER SPEED = 7

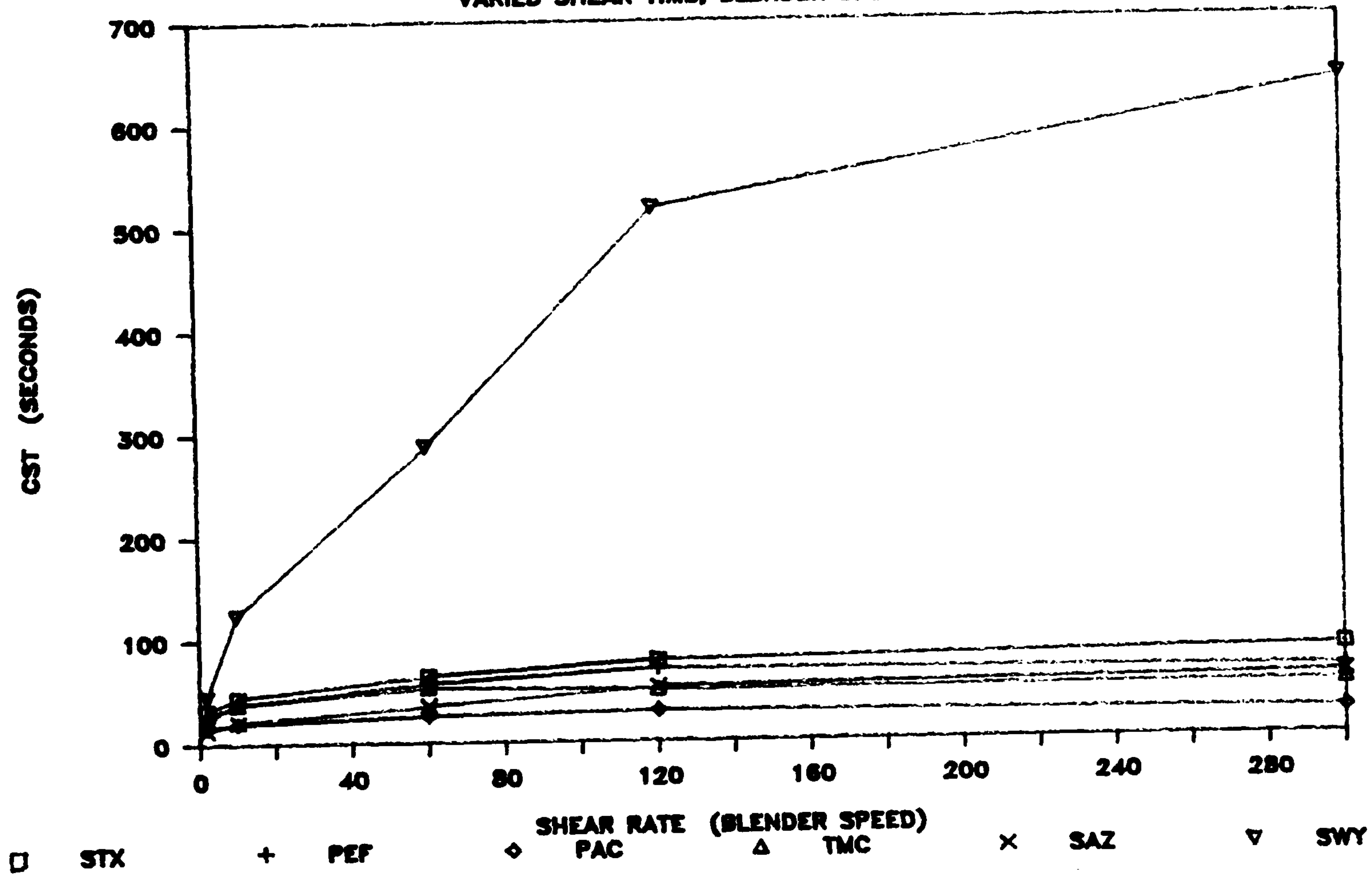


FIGURE 35, CST, 0.5% KCL

VARIED SHEAR RATE, SHEAR TIME = 120 SEC

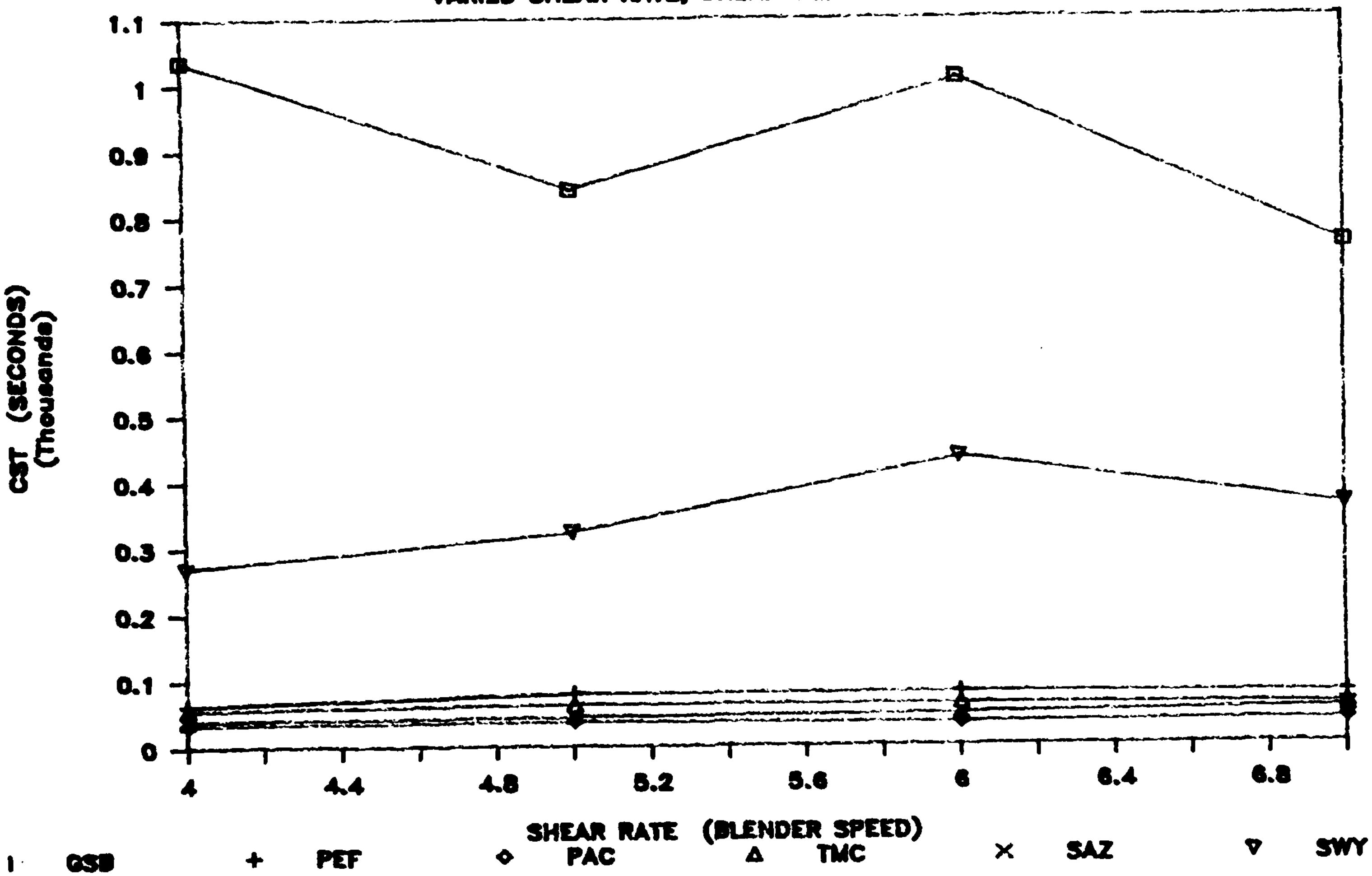


FIGURE 36. CST, 0.5% KCL

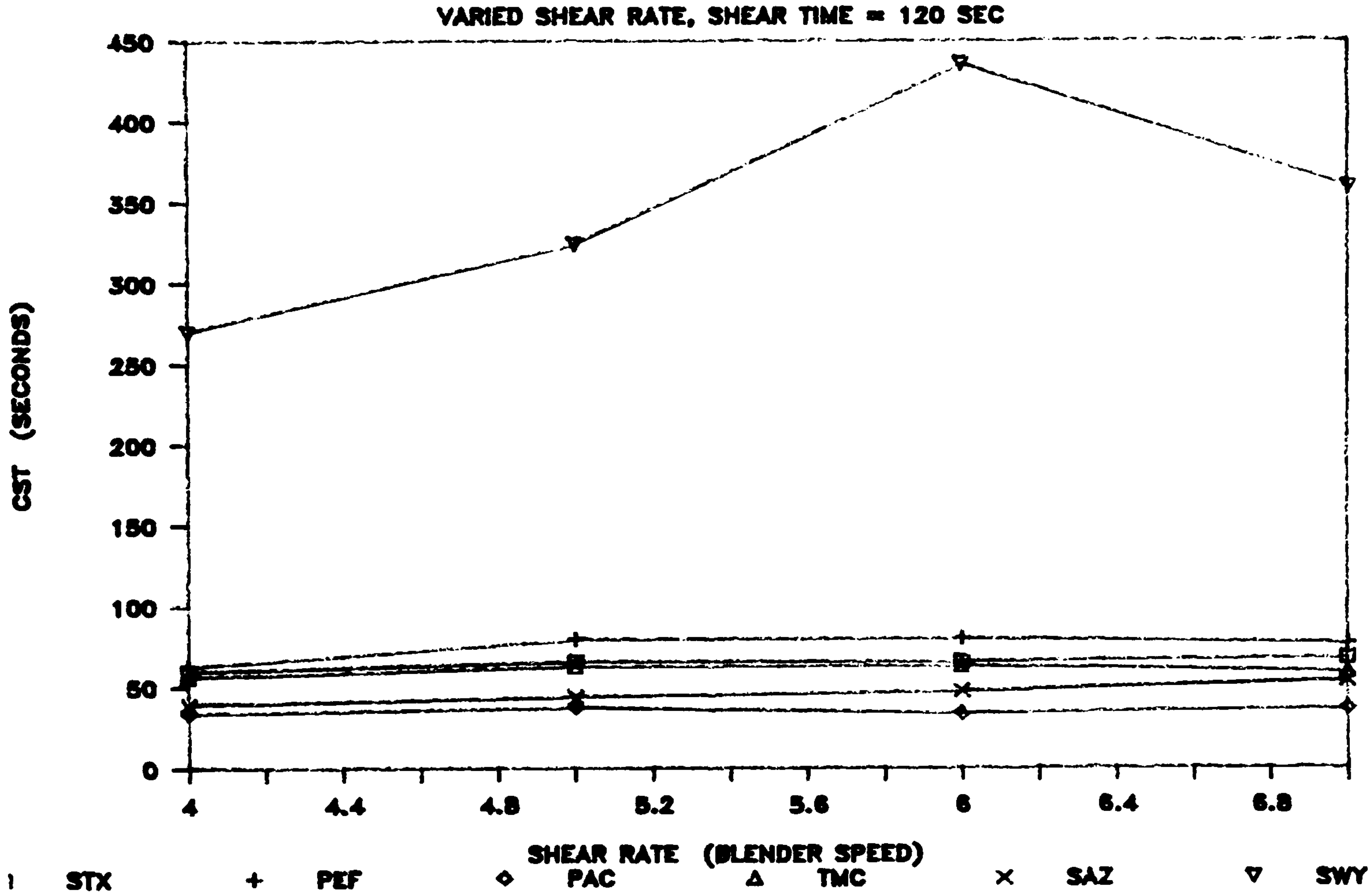


FIGURE 37. CST, 15% KCL

VARIED SHEAR TIME, BLENDER SPEED 7

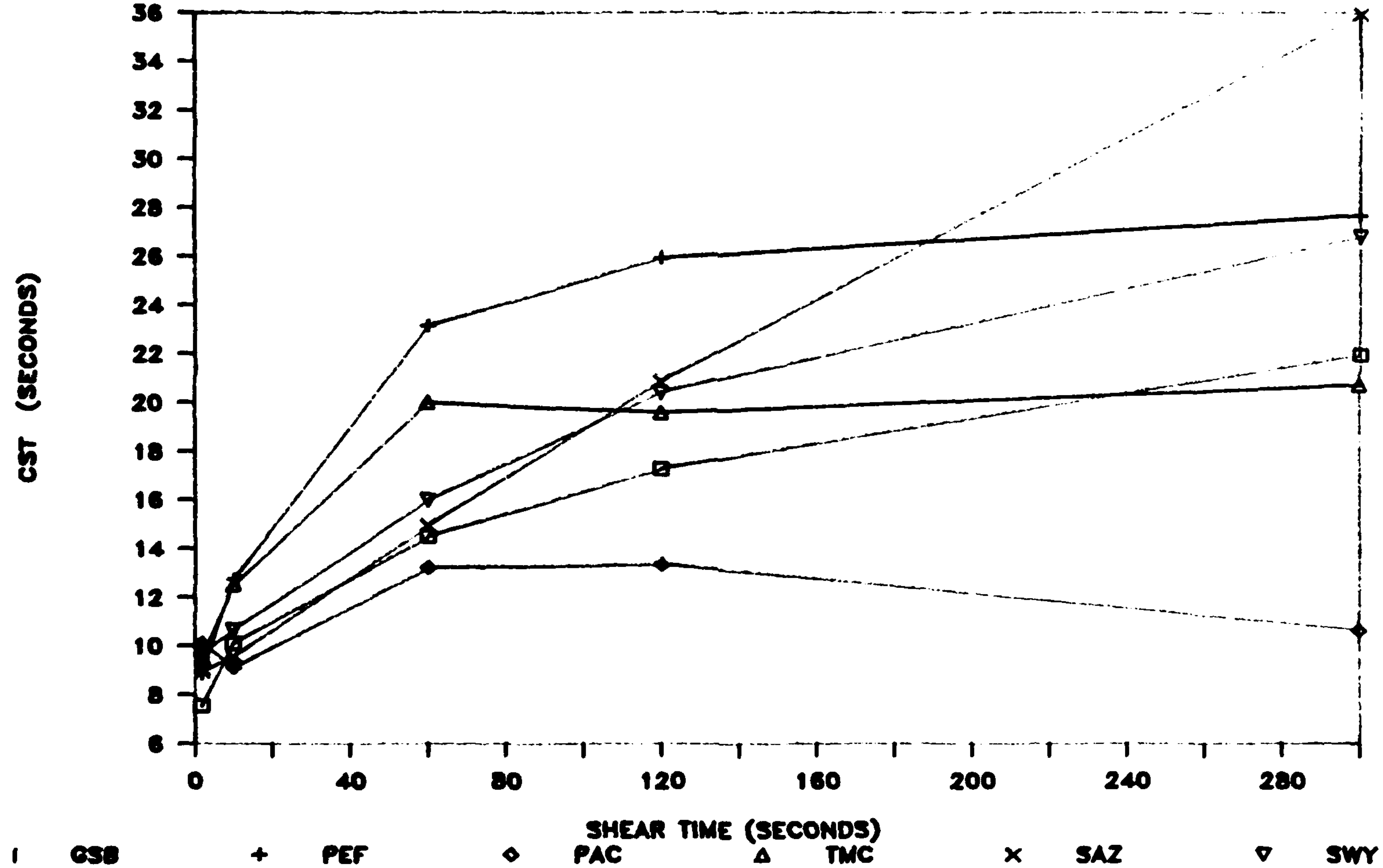


FIGURE 38. CST, 15% KCL

VARIED SHEAR TIME, BLENDER SPEED 7

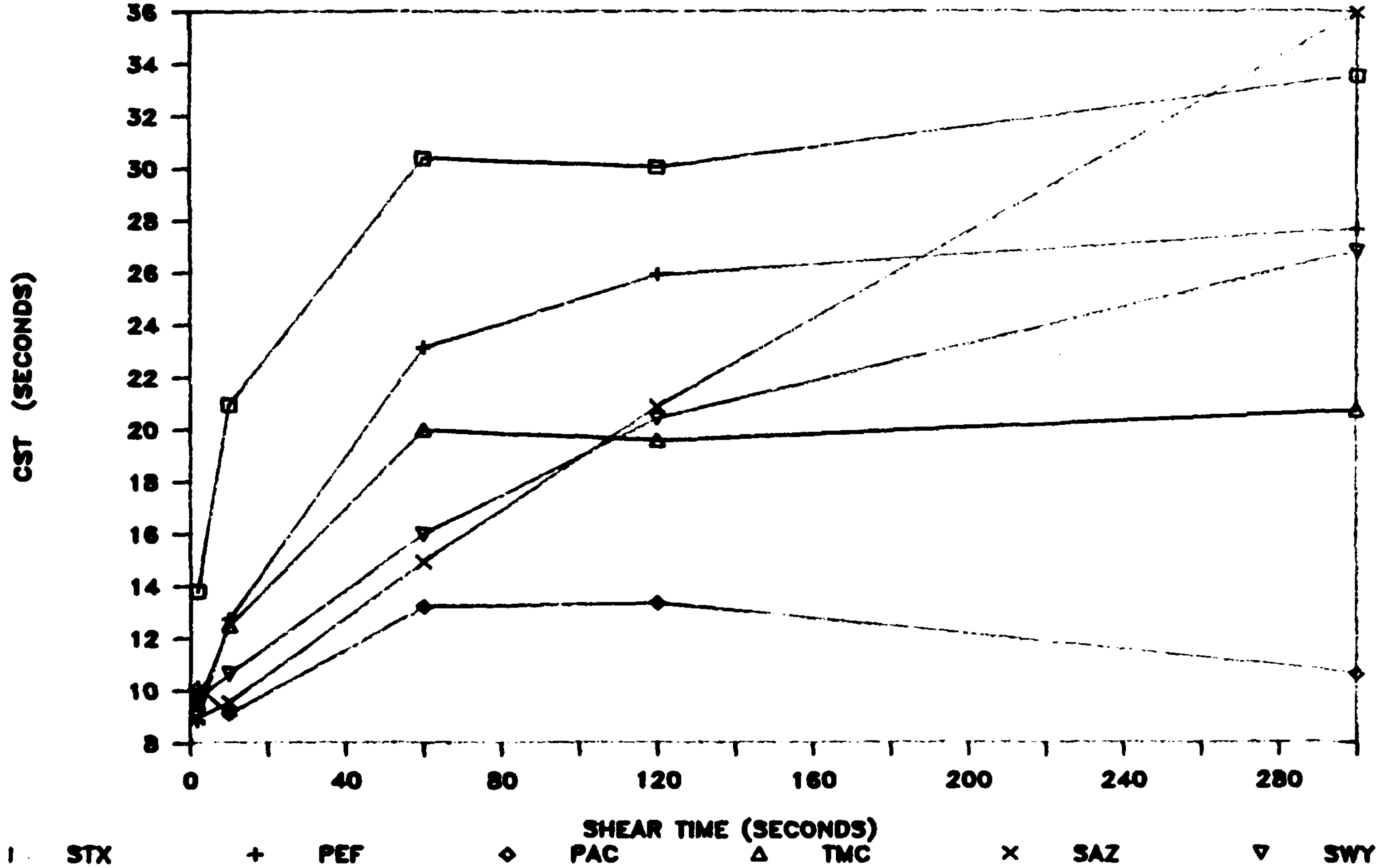


FIGURE 39. CST, 15% KCL

VARIED SHEAR RATE, TIME = 120 SEC

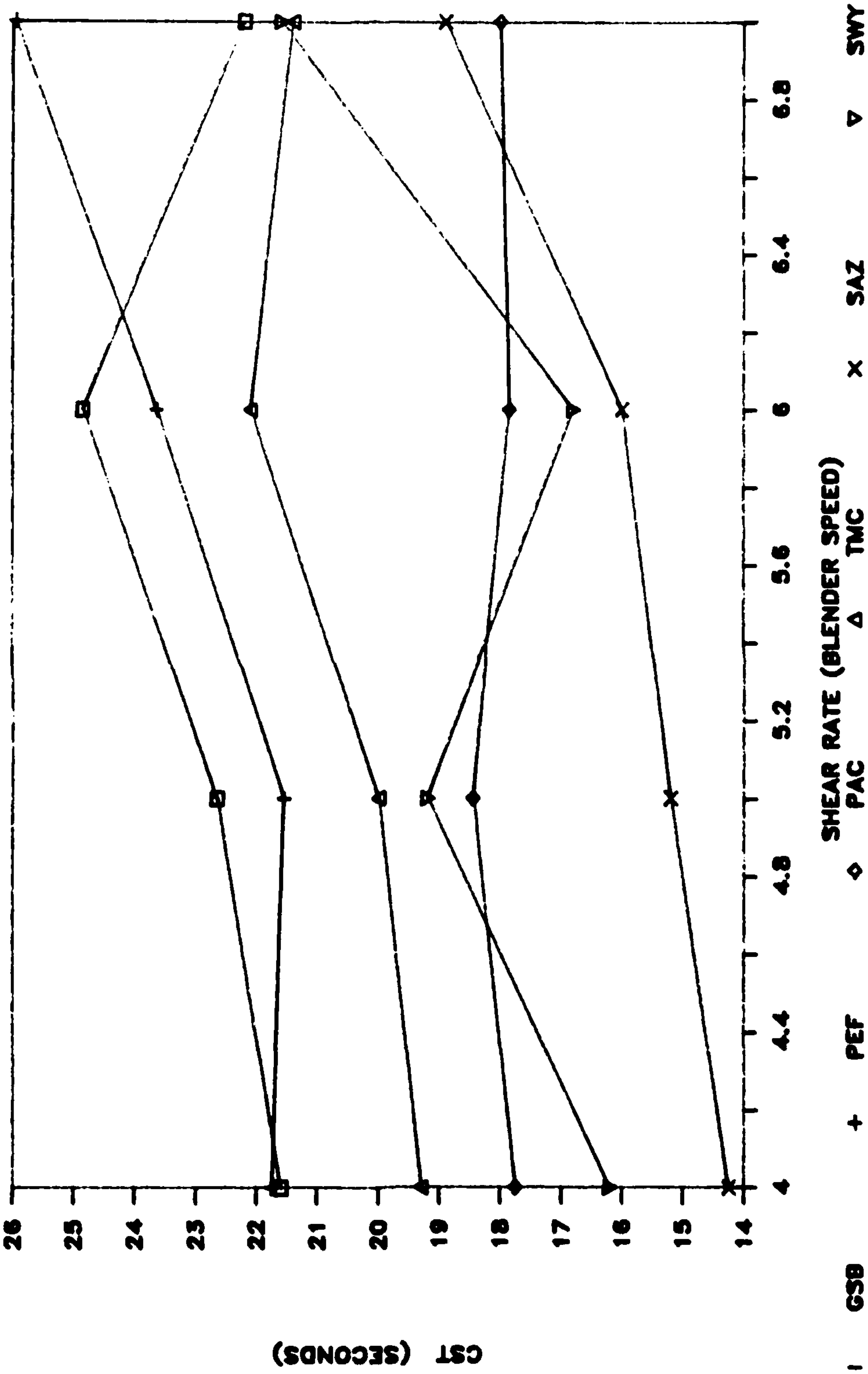


FIGURE 40. CST, 15% KCL

VARIED SHEAR RATE, TIME = 120 SEC

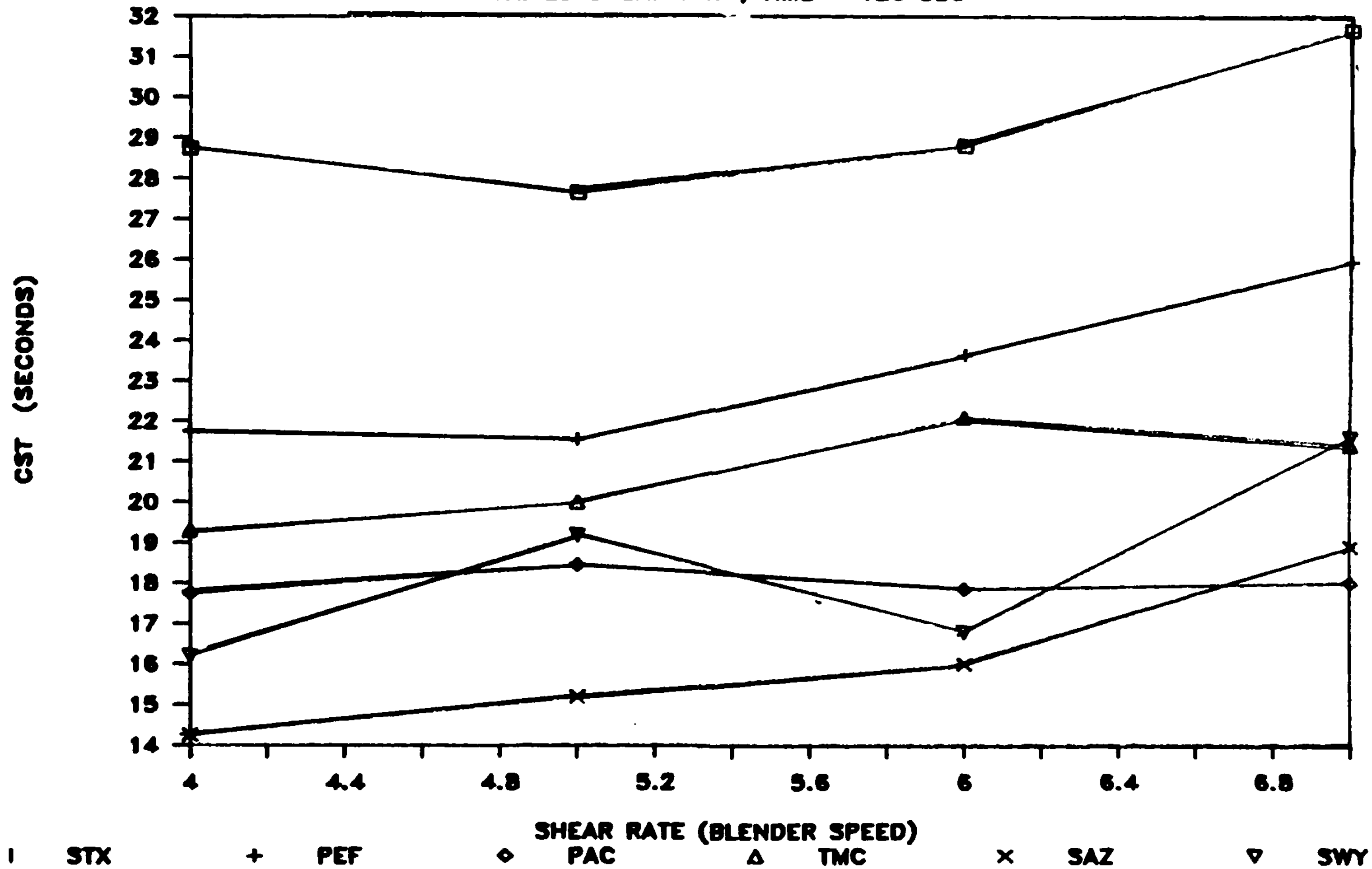


FIGURE 41. CST, STANDARD ARIZONA

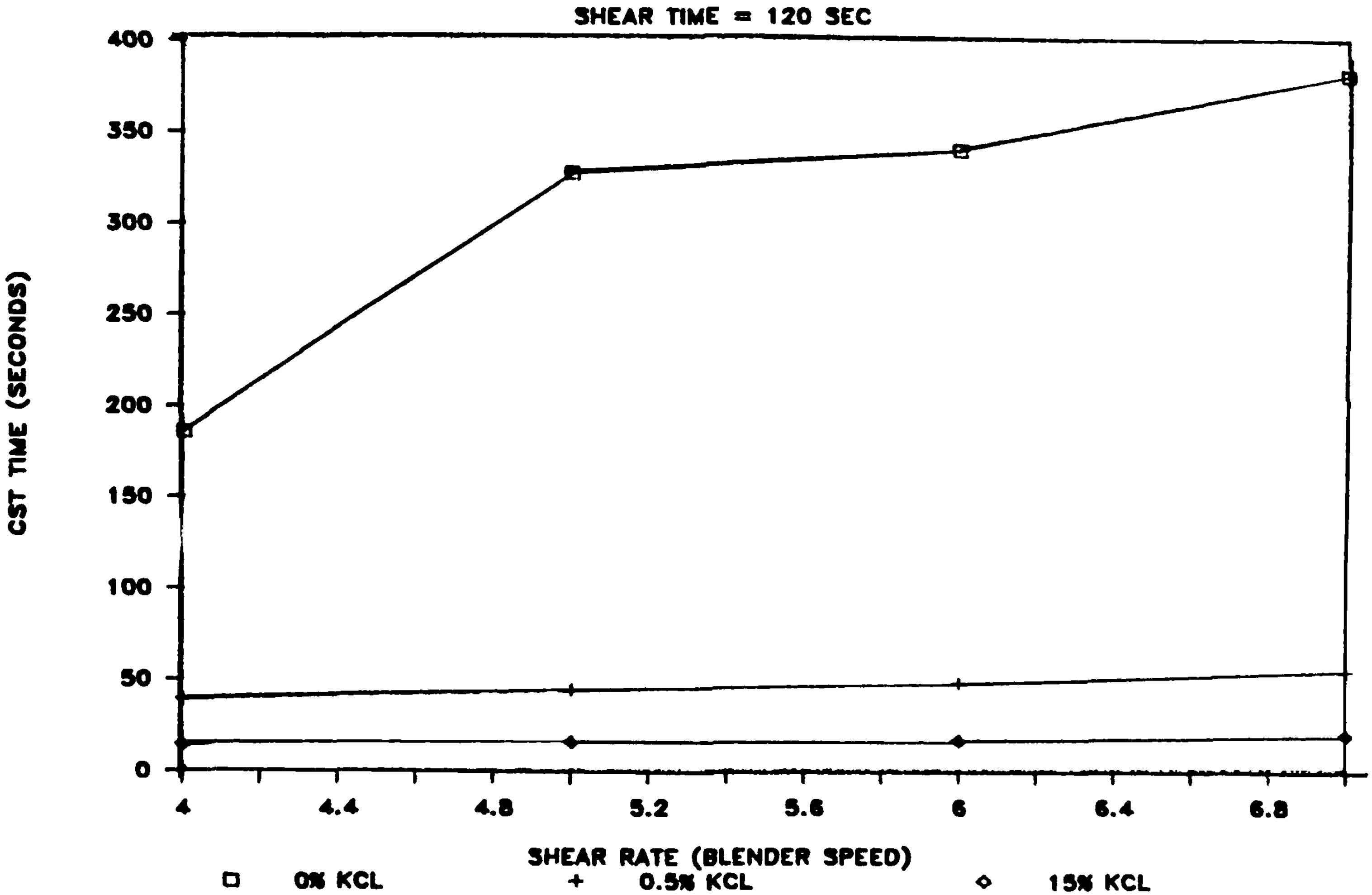


FIGURE 42. CST, STANDARD WYOMING

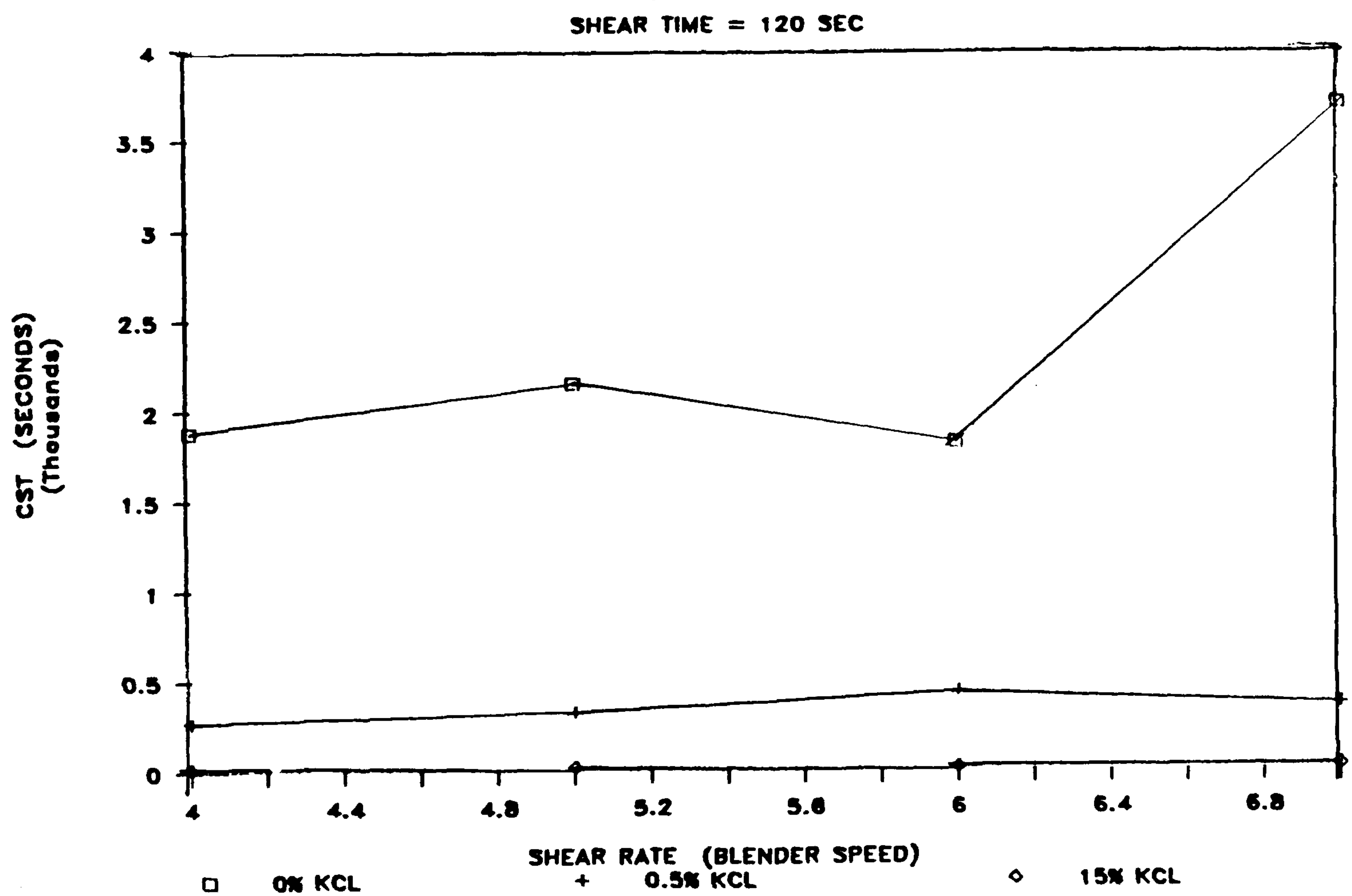
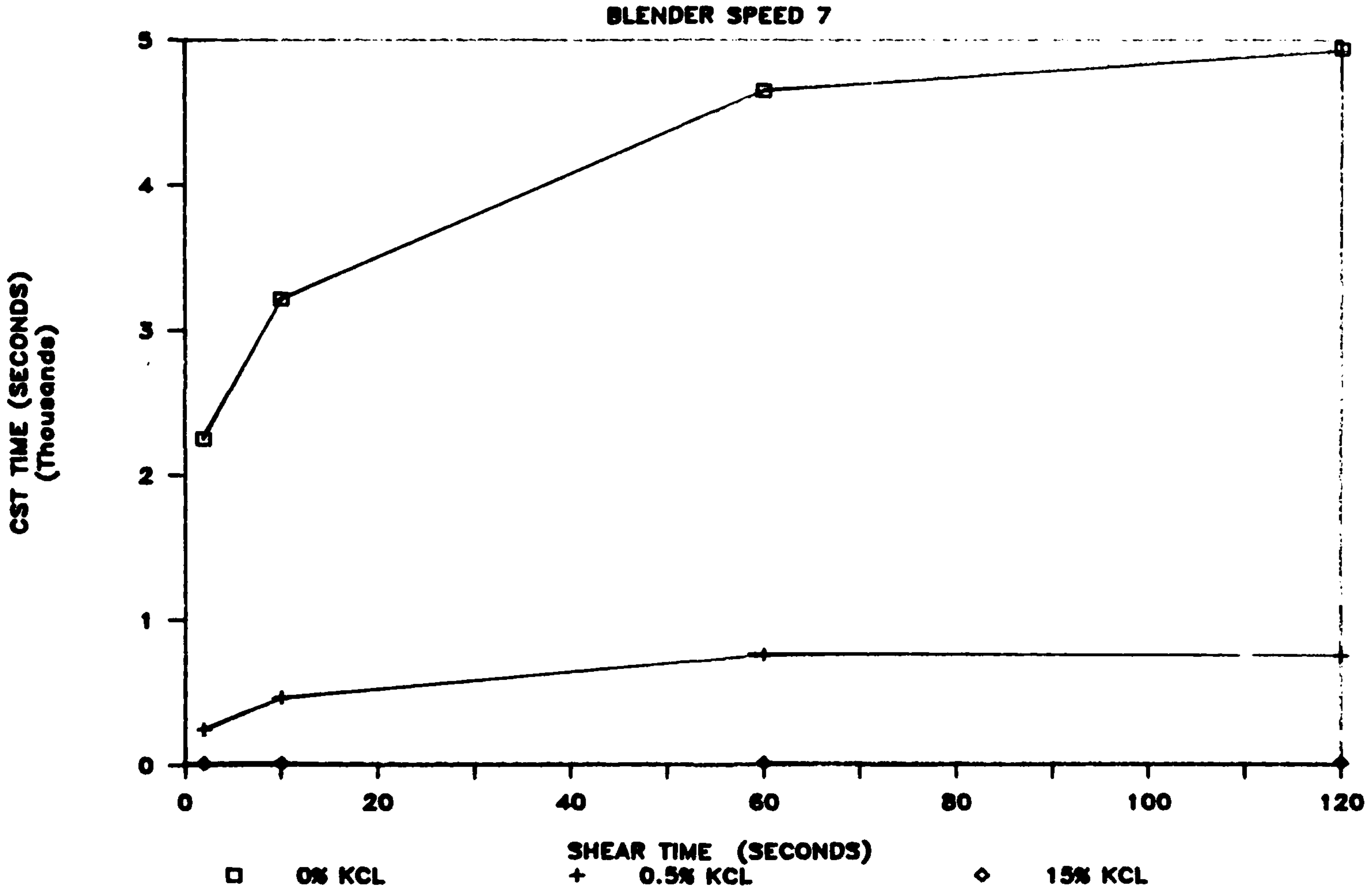


FIGURE 43. CST, GOLD SEAL BENTONITE



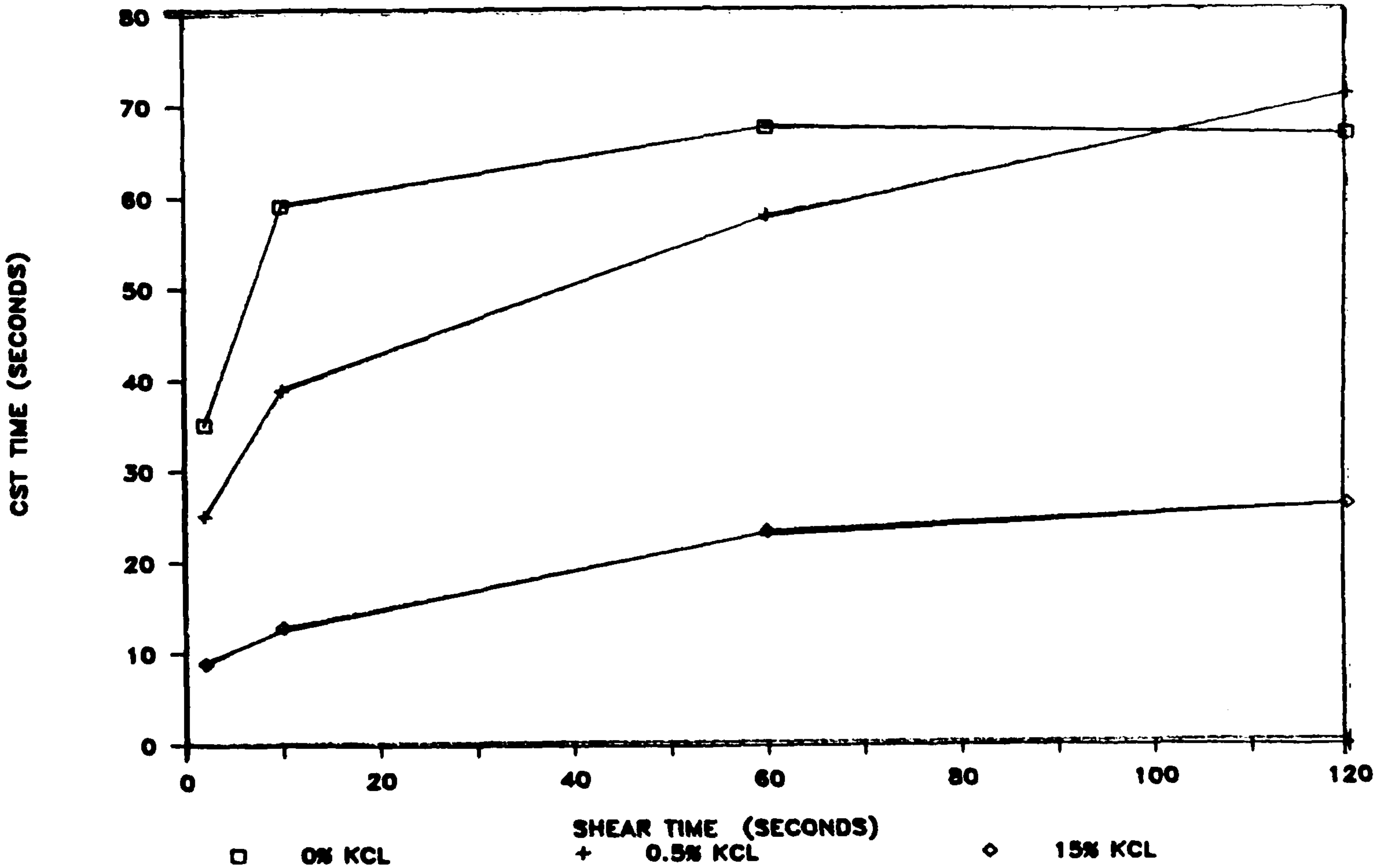


FIGURE 44. CST, PHILLIPS EKOFISK
BLENDER SPEED = 7

FIGURE 45. CST, PHILLIPS ANDREWS CO.

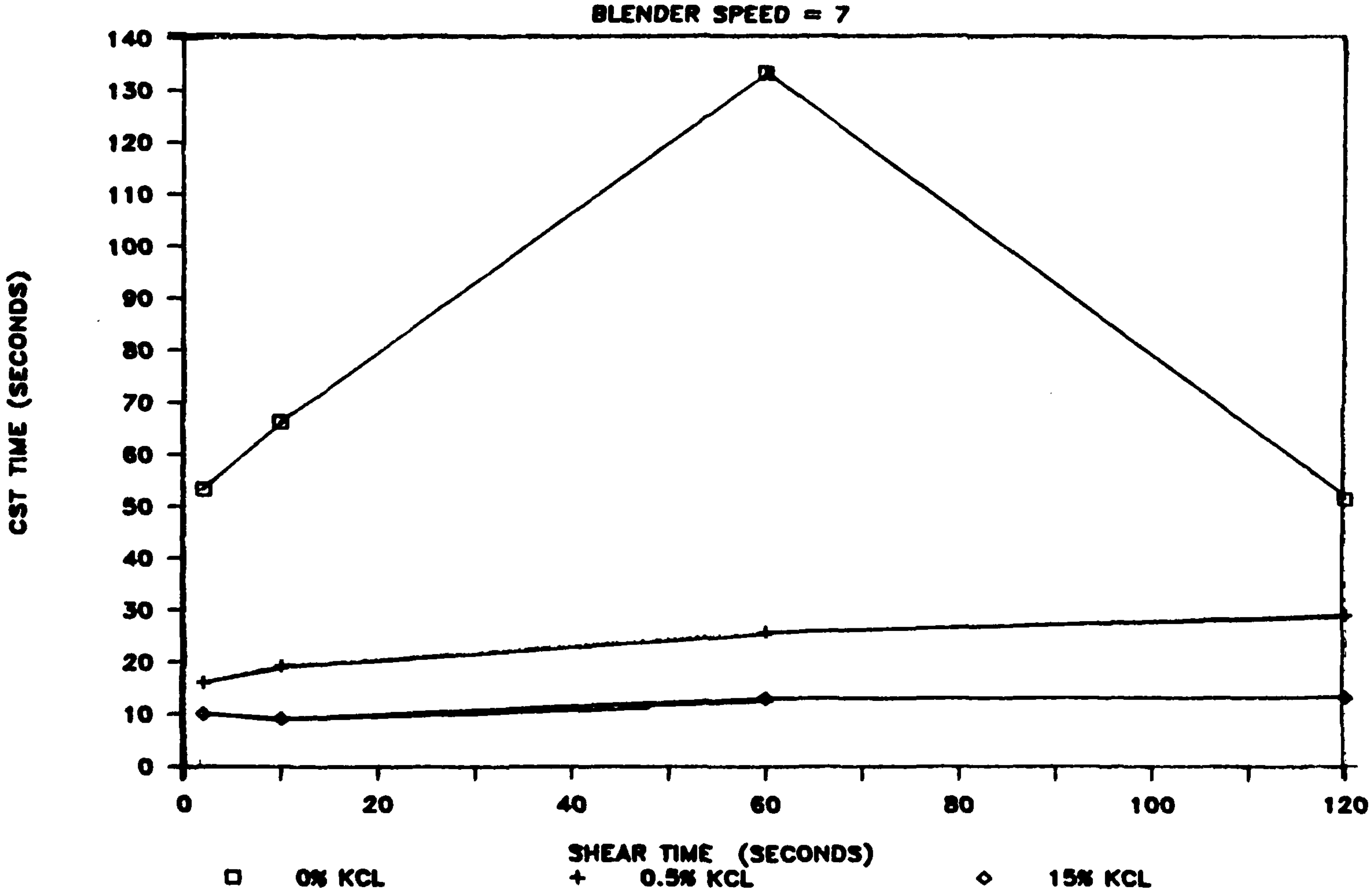


FIGURE 46. CST, TEXACO MISS. CANYON

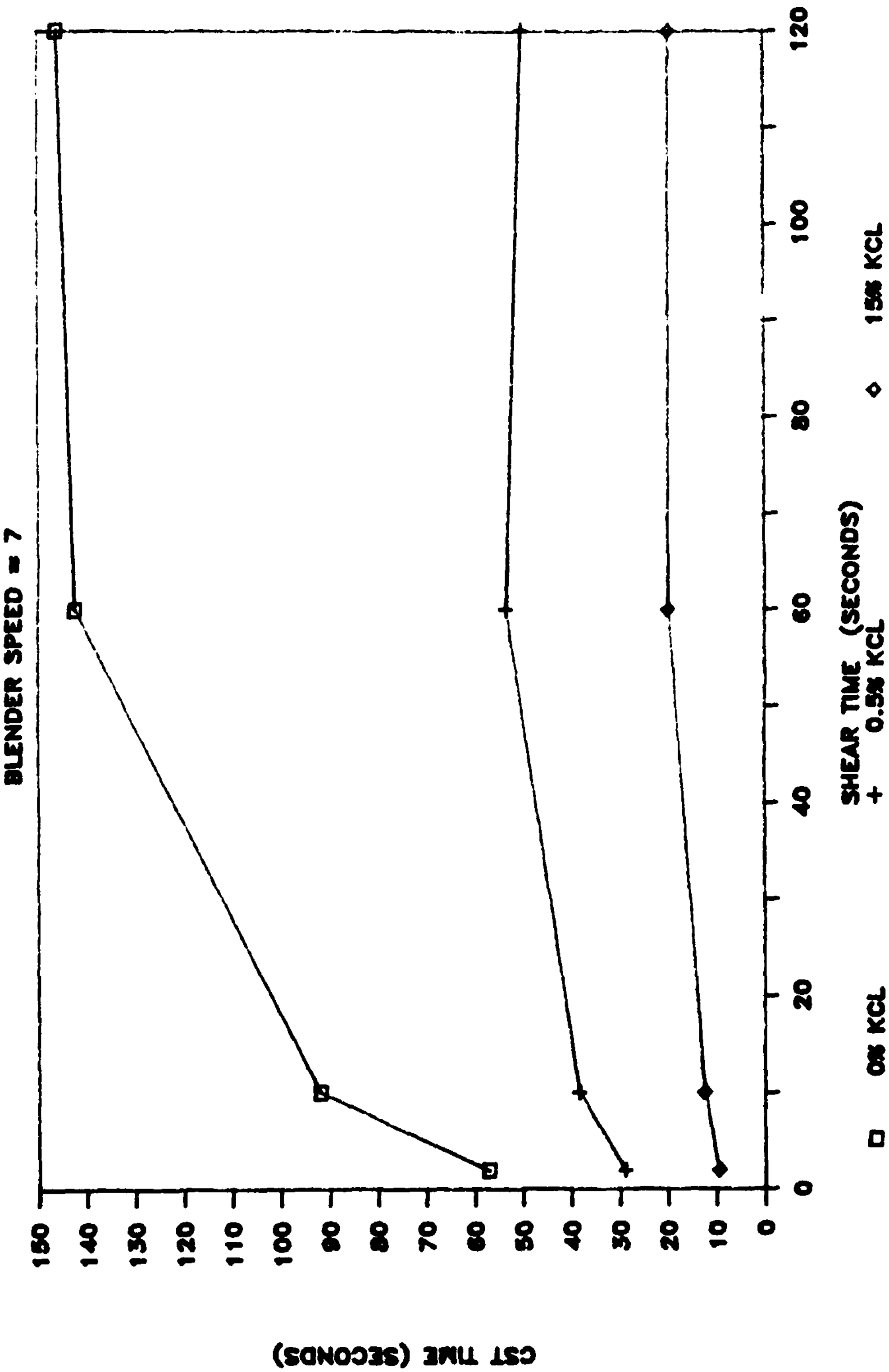


FIGURE 47. CST, PIERRE TEXACO

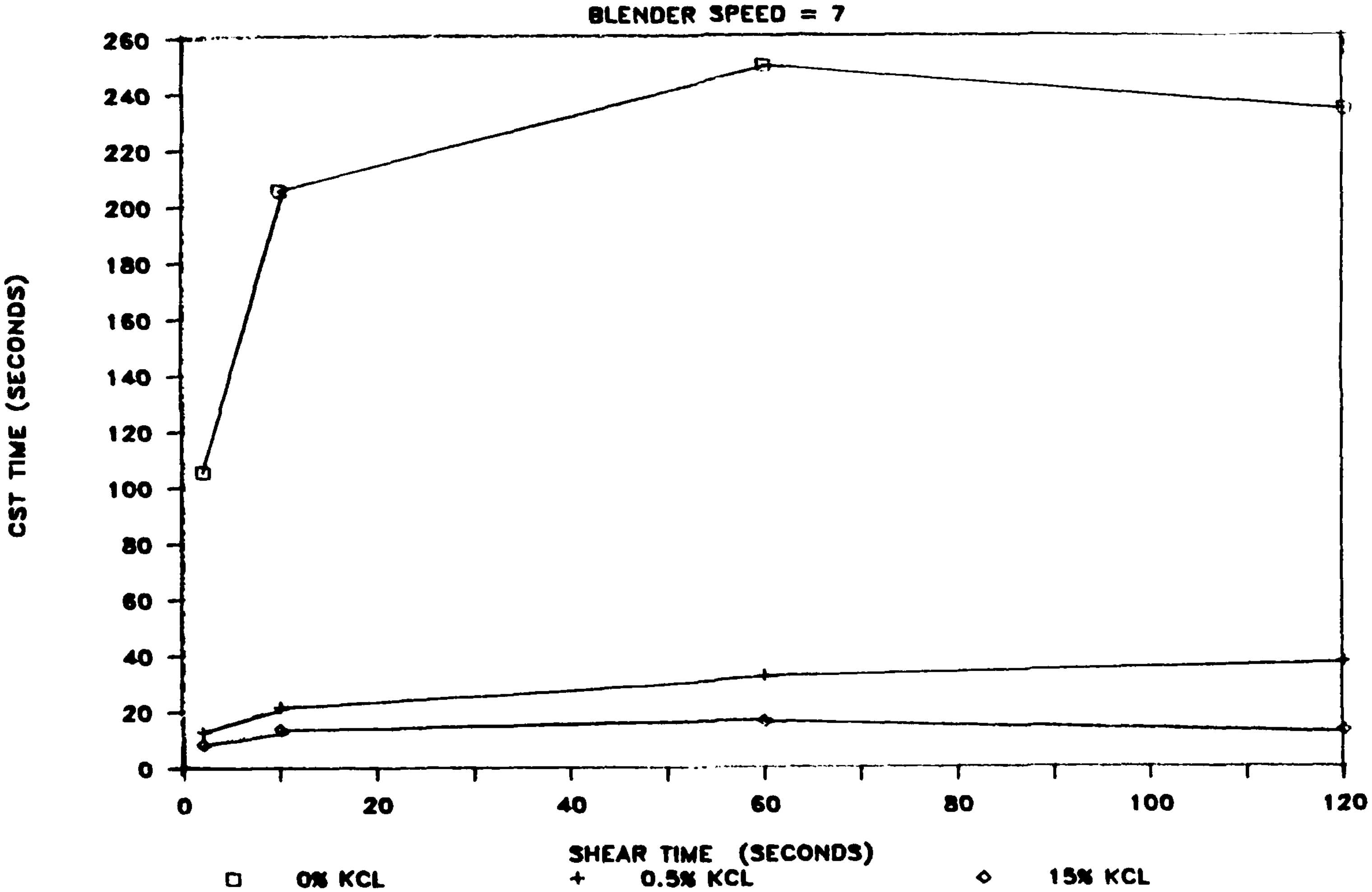


FIGURE 48. CST, PIERRE MUDTECH

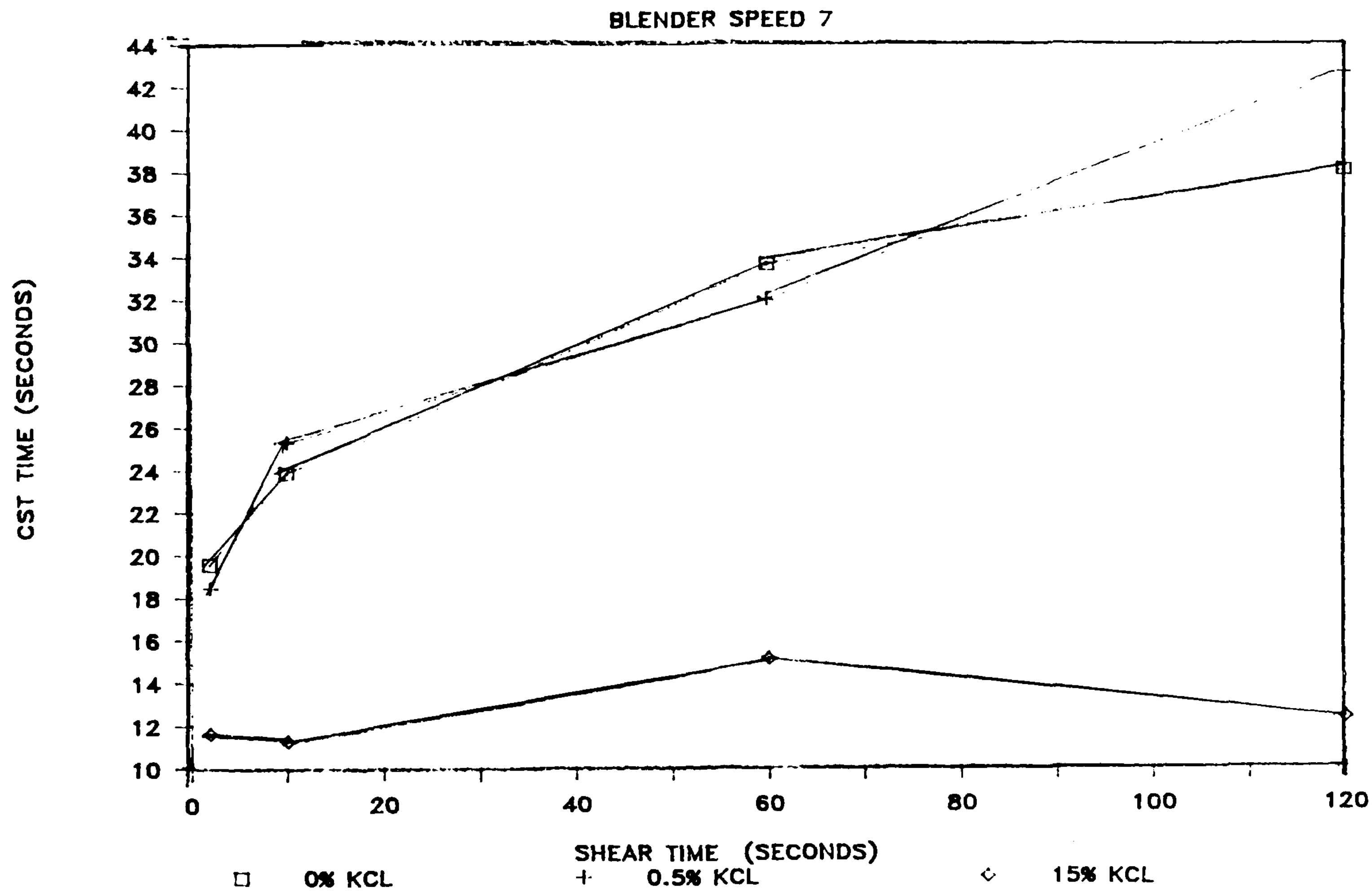


FIGURE 49. CST, MANCOS MUDTECH

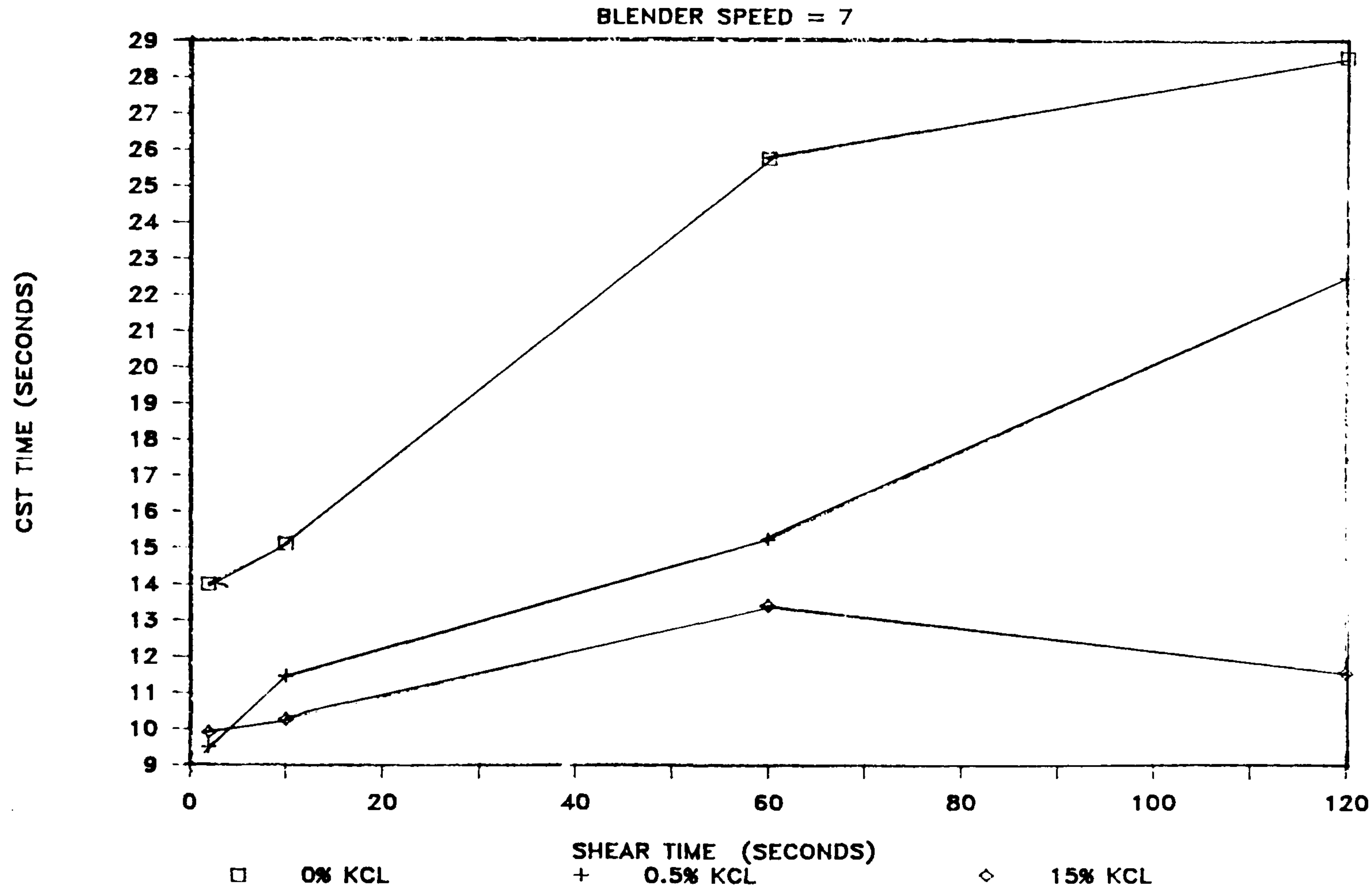


FIGURE 50. CST, STANDARD TEXAS

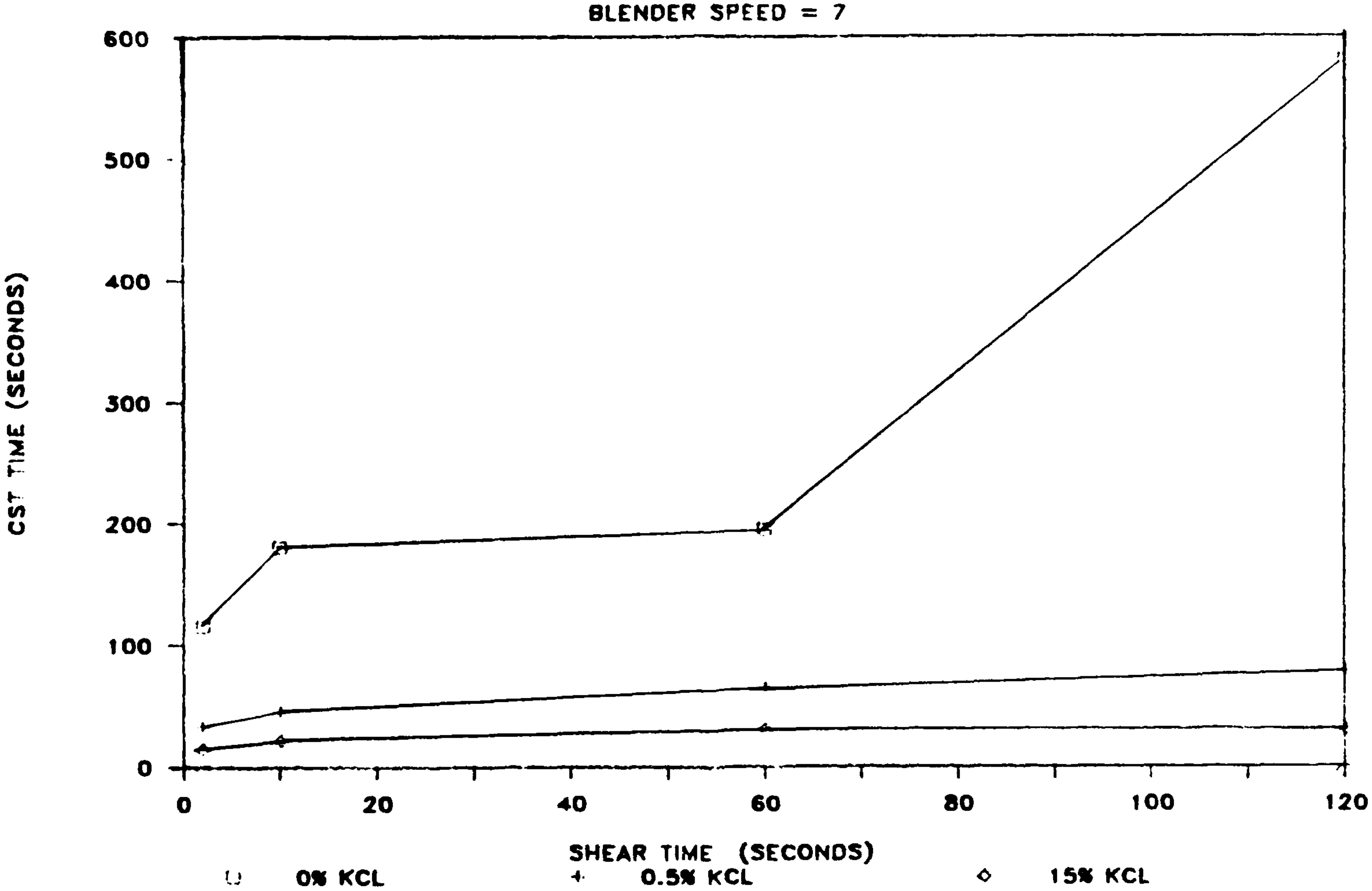


FIGURE 51. CST, STANDARD ARIZONA

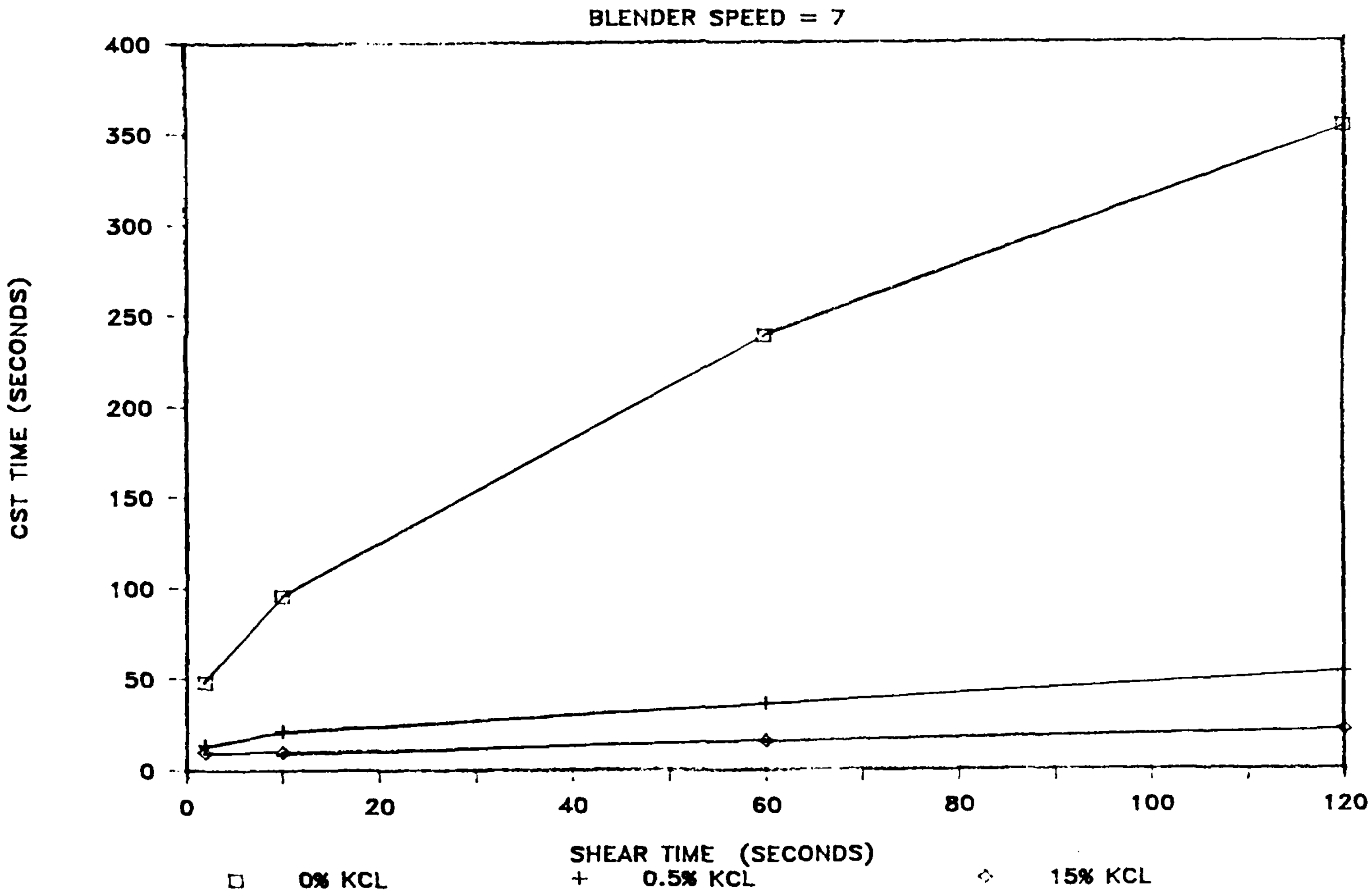


FIGURE 52. CST, STANDARD WYOMING

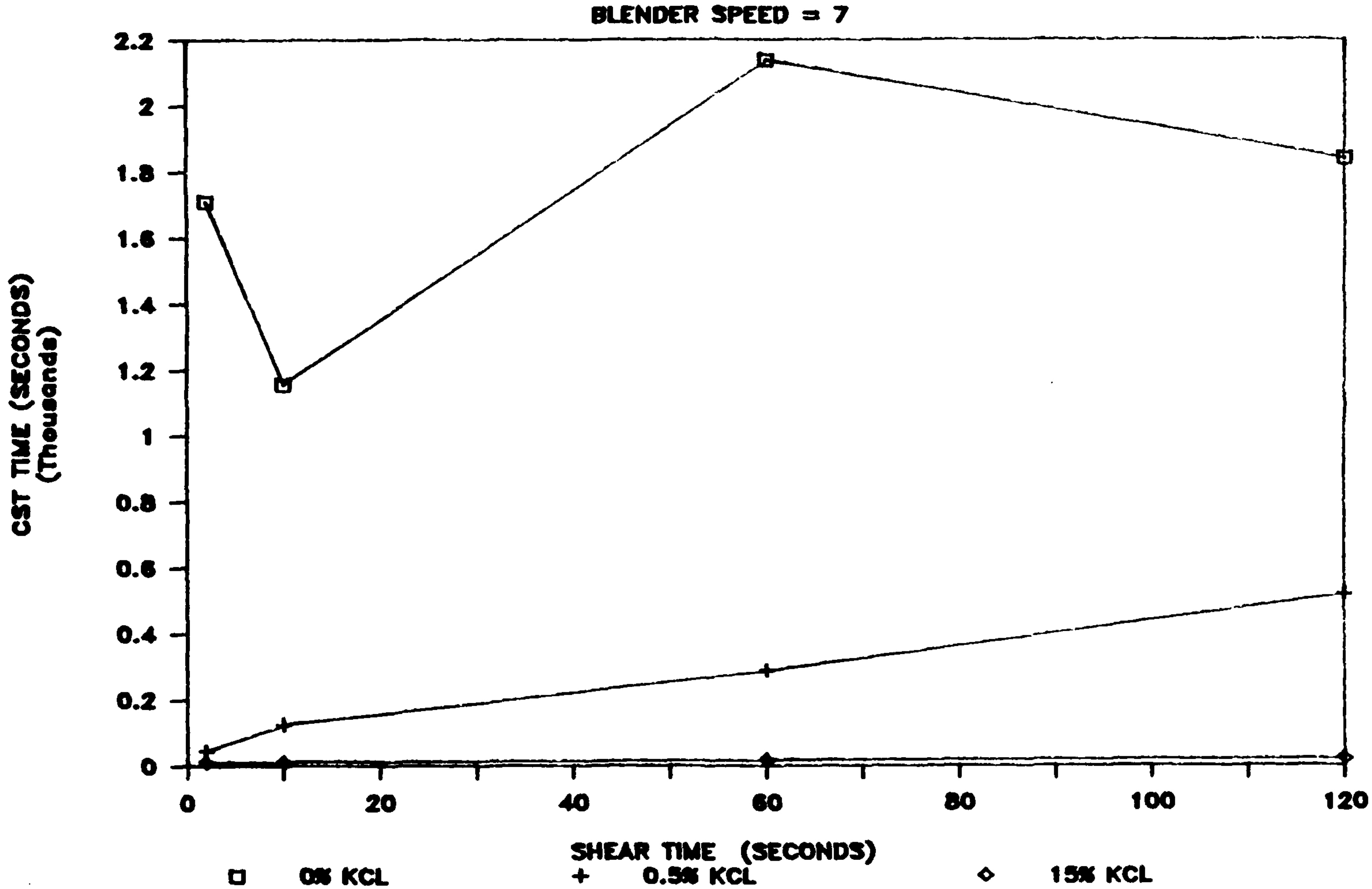


FIGURE 53. CST, STANDARD ARIZONA

BLENDER SPEED = 7

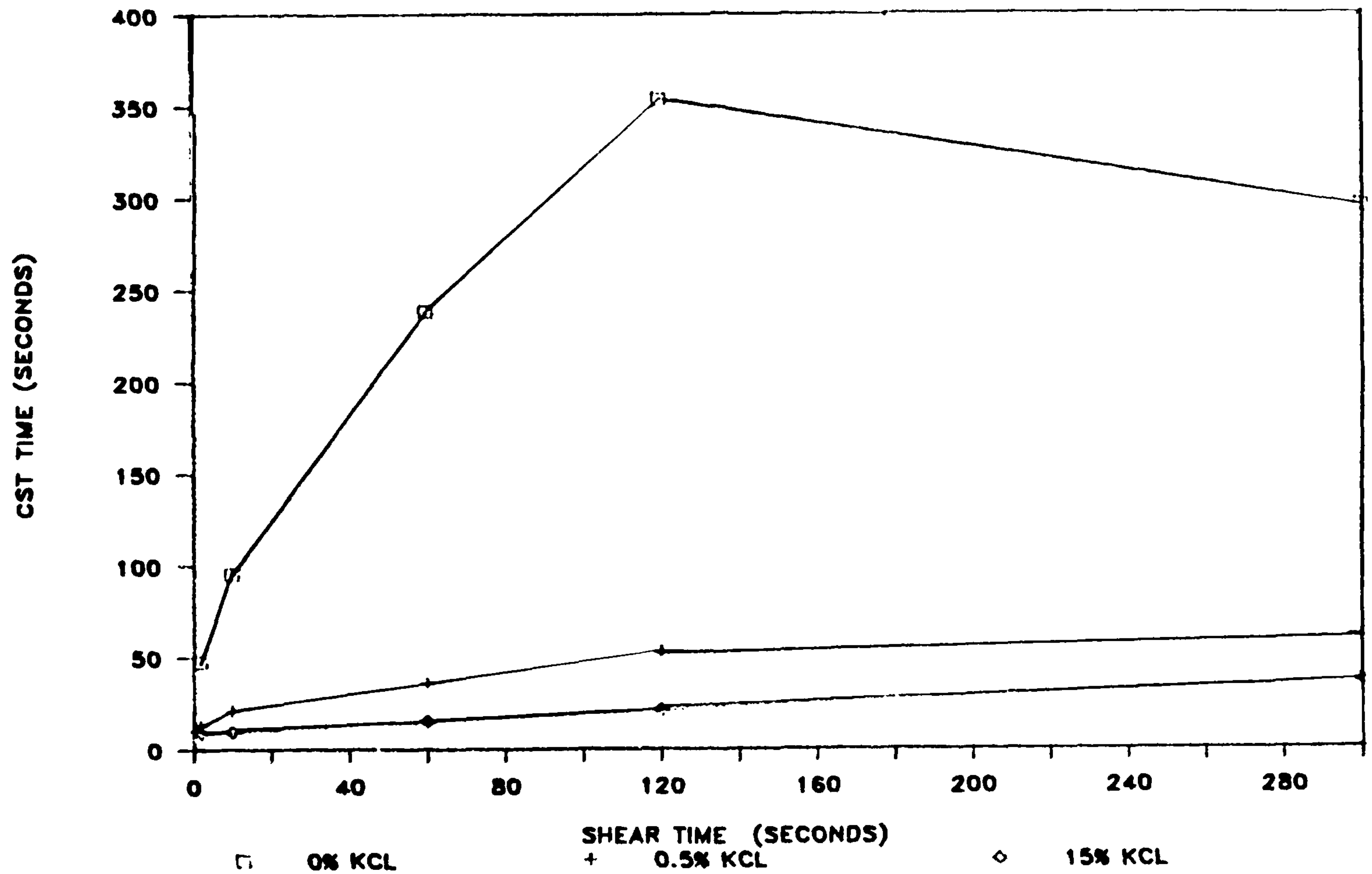
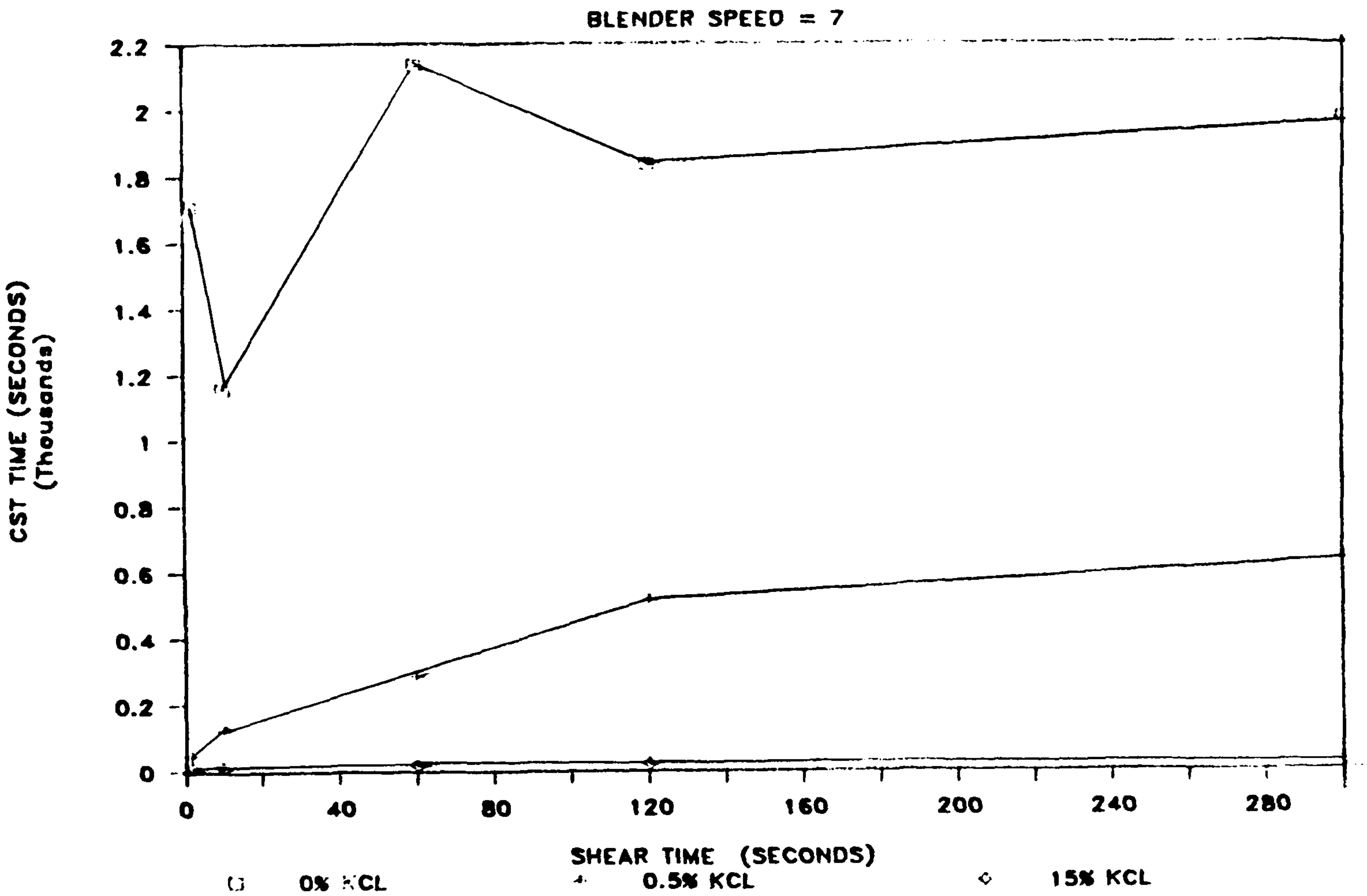


FIGURE 54. CST, STANDARD WYOMING



CHAPTER 4

DISCUSSION OF RESULTS

4.1 Varied Shear Rate

Gold Seal Bentonite, Standard Texas, Standard Arizona and Standard Wyoming had the largest CST values. Also, the Cst value varied with time in a nonlinear fashion. This is in contrast to Wilcox's assumption of straight line dispersion profiles. Compared to the four standard shales, Phillips Ekofisk, Phillips Andrews County, Texaco Mississippi Canyon, Pierre Texaco, Pierre Mudtech and Mancos Mudtech have relatively low CST values. Also, the dispersion profiles are essentially horizontal, indicating all of the collodial clay particles breakdown instanetously, or at least in a very short time.

4.2 Varied Shear Rate

The curves of CST vs. Shear Rate give an indication of bond type. As was the case with varied shear time, Gold Seal Bentonite, Standard Wyoming, Standard Texas and Standard Arizona had high CST values relative to Phillips Ekofisk, Pierre Mudtech, Phillips Andrews County, Texaco Mississippi Canyon, Pierre Texaco and Mancos Mudtech. The CST of Pierre Texaco reaches a maximum value and then declines at a higher shear rate. The remaining shales exhibit increasing CST with increasing shear rate. The drop in CST values for the Standard Texas and Pierre Texaco shales can be attributed to aggregation. Aggregation occurs when the maximum dispersion has been reached. Mancos Mudtech and Pierre Mudtech have very low CST values that essentially remain constant under varying shear rate. Since CST values reflect the swelling potential of shales, both Pierre Mudtech and Mancos Mudtech would appear to be low swelling clays. Conversely, since the CST values for Gold Seal Bentonite, Standard Texas, Standard Wyoming and Standard Arizona are very high, the CST test predicts these clays to be high swelling.

4.3 Effect of KCL on CST values.

For all the shales tested, an increase in KCL concentration decreased the magnitude of the CST value. This effect can be attributed to the inhibiting ability of the potassium ion. This inhibiting ability is seen best when looking at the high swelling clays: Gold Seal

Bentonite, Standard Texas, Standard Wyoming and Standard Arizona. The high swelling shales require a larger KCL concentration to significantly reduce the magnitude of the CST value relative to the low swelling shales. The inhibitive ability of the potassium ion has been noted several times in the literature

4.4 CST vs. X-Ray Diffraction

As mentioned throughout the literature, monmorillonite is the clay most sensitive to swelling. Illite also swells but not to the same extent as montmorillonite. On the other hand, kaolinite and chlorite don't swell to an appreciable extent.

From the X-Ray diffraction data shown in Table 5, Gold Seal Bentonite, Standard Arizona, Standard Texas and Standard Wyoming all have a clay content that is 100% montmorillonite. Also as discussed earlier, these shales were predicted to be high swelling from the CST data. Pierre Texaco also has a clay content that is high in montmoillonite. However its clay fraction is only 57%. As a result, X-Ray diffraction predicts Pierre Texaco shale should swell to a moderate extent. Cst data also predicts moderate swelling for the Pierre Texaco shale.

According to the CST data, Phillips Ekofisk, Phillips Andrews County and Texaco Mississippi Canyon should also be moderately swelling shales. X-Ray diffraction data also predicts moderate swelling since Phillips Andrews County and Texaco Mississippi Canyon contain a large percentage of mixed layer montmorillionite/illite and Phillips Ekofisk contains a fairly large percentage of montmorillionite.

X-Ray diffraction data for Mancos Mudtech and Pierre Mudtech predict low swelling for these shales. This is due to the low clay content of these two shales. Also, Mancos Mudtech contains a large amount of kaolinite and chlorite.

4.5 CST vs Specific Surface Area

The specific surface area of a shale is a measure of reactivity. This is an indication of the likelihood of the shale to swell. The shales with the highest specific surface area were Gold Seal Bentonite, Standard Texas, Standard Arizona and Standard Wyoming. As mentioned earlier, CST data also predicts these shales to be high swelling.

The specific surface area of Phillips Ekofisk, Pierre Mudtech, Phillips Andrews County, Texaco

Mississippi Canyon and Pierre Texaco predict that these shales would exhibit moderate swelling. CST data agrees with this prediction with the exception of Pierre Mudtech. CST predicts Pierre Mudtech to be low swelling the specific surface area predicts moderate swelling for Pierre Mudtech. The results of CST and specific surface area for Mancos Mudtech are in agreement. Both tests predict low swelling for Mancos Mudtech.

4.6 Methylene Blue Capacity vs. CST

The methylene blue test measures the cation exchange capacity of the shales. Methylene blue capacity also gives an indication of the clay content of the shale. The shales that had the highest cation exchange capacity were Gold Seal Bentonite, Standard Arizona, Standard Texas and Standard Wyoming. This result, which predicts high swelling for these shales, is in agreement with CST data. Methylene blue adsorption data for Phillips Ekofisk, Pierre Mudtech, Phillips Andrews County, Texaco Mississippi Canyon and Pierre Texaco to swell moderately. With the exception of Pierre Mudtech, this prediction is in agreement with CST data. Cation exchange capacity data predicits Pierre Mudtech to swell moderately while CST data predicts the shale to be low swelling. Both CST and cation exchange capacity data both predict Mancos Mudtech to be low swelling.

4.7 Ensilin vs CST

The ensilin apparatus measures the amount of fluid adsorbed by a shale sample. Wilcox and Fisk have shown that fluid adsorption profiles are generally linear. This is also the case for the tests run on the shales at CESE. Wilcox and Fisk defined the y-intercept of the adsorption profile as the swelling index. The swelling index provides an indication of fluid adsorbed due to surface colloidal clay particles. The swelling index can be used to predict the swelling behavior of shales.

As with all the previous experiments, the swelling index predicts Standard Arizona, Standard Wyoming, Gold Seal Bentonite and Standard Texas to be high swelling. Pierre Texaco, Texaco Mississippi Canyon, Phillips Andrews County, Pierre Mudtech and Phillips Ekofisk are predicted to swell moderately. CST data predicts the same result with the exception of Pierre Mudtech. The CST predicts Pierre Mudtech to be low swelling.

4.8 Discussion of the CST test

The capillary suction time test is fast and easy to use. It can be performed at the rigsite. However, data from the CST test is not very reproducible. Therefore the data obtained should be used qualitatively. The test is useful and can help drilling engineers predict where the troublesome shale zones are located.

4.9 Classification of Test Shales

Table 7 is a presentation of a shale classification scheme using CST, X-Ray diffraction, Methylene Blue Capacity, Specific Surface Area and Ensilin data. As can be seen from Table 7, the shales Gold Seal Bentonite, Standard Arizona, Standard Texas and Standard Wyoming are classified as high swelling shales. Phillips Ekofisk, Phillips Andrews County, Texaco Mississippi Canyon, Pierre Texaco are predicted to display moderate swelling while Mancos Mudtech is predicted to be a low swelling shale. Pierre Mudtech is difficult to classify due to conflicting results. CST predicts low swelling while the other experiments predict moderate swelling for Pierre Mudtech.

TABLE 7.
SHALE CLASSIFICATION

SAMPLE	CST HIGH	CST MEDIUM	CST LOW	XRD HIGH	XRD MEDIUM	XRD LOW	SSA HIGH	SSA MEDIUM	SSA LOW	MBT HIGH	MBT MEDIUM	MBT LOW	ENSILIN HIGH	ENSILIN MEDIUM	ENSILIN LOW
GSB	x			x			x			x			x		
SAZ	x			x			x			x			x		
STX	x			x			x			x			x		
SWY	x			x			x			x			x		
PAC		x			x			x			x			x	
PEF		x			x			x			x			x	
PTX		x			x			x			x			x	
TMC		x			x			x			x			x	
MMT			x			x			x			x			x
PMT			x		x			x			x			x	

CHAPTER 5

CONCLUSIONS

1. The Capillary Suction Time test is simple and easy to use, allowing operators to conduct the test at the rigsite. However because of difficulty in reproducing results, the test should only be used qualitatively.

2. The CST along with the Methylene Blue, Specific Surface Area and Ensilin tests performed at the Center for Earth Science and Engineering accuratly predicts shale swelling and dispersion. The tests have the added advantage of being able to be conducted relatively quickly. These tests could be carried out at the rigsite while the drilling is taking place.

3. The experiments conducted also demonstrated the usefulness of KCL as an inhibitor of shale swelling and dispersion. From the CST data, it can be seen that KCL concentrations as low as 0.5% are effective in controlling the swelling of Phillips Ekofisk, Phillips Andrews County, Texaco Mississippi Canyon and Pierre Texaco. However a greater concentration of KCL is required to inhibit the swelling of Gold Seal Bentonite,

Standard Arizona, Standard Wyoming and Standard Texas. It is recommended that more concentrations of KCL be tested of the high swelling clays in order to determine the minimum concentration required to inhibit swelling and dispersion.

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VITA

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This thesis was typed by the author.